PB82-208000

Preliminary Results of the Nationwide Urban Runoff Program. Volume II. Appendices

(U.S.) Environmental Protection Agency
Washington, DC

1 Mar 82

U.S. Department of Commerce
National Technical Information Service
NTIS

PB82-208000

PRELIMINARY RESULTS
OF THE
NATIONWIDE URBAN RUNOFF PROGRAM

VOLUME II - APPENDICES

Water Planning Division
U.S. Environmental Protection Agency
Washington, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

BIBLIOGRAPHIC INFORMATION

PB82-208000

Preliminary Results of the Nationwide Urban Runoff Program.
Volume II. Appendices.

1 Mar 82

PERFORMER: Environmental Protection Agency, Washington, DC.
Water Planning Div.

See also Volume 1, PB82-207994. Also available in set of 3 reports PC E99, PB82-207978.

Partial contents; Early perceptions; The Nationwide urban runoff program; Urban runoff perspectives; Water quantity concerns; Water quantity and quality control; Urban runoff pollutant loads; Water quality effects; Evaluation of controls; Quality assurance and quality control; Receiving water effects; Evaluation of controls.

KEYWORDS: *Runoff, *Water pollution, *Urban areas, *Storm water runoff.

Available from the National Technical Information Service,
Springfield, Va. 22161

PRICE CODE: PC A99/MF A01

PRELIMINARY RESULTS
OF THE
NATIONWIDE URBAN RUNOFF PROGRAM

March 1, 1982

VOLUME II - APPENDICES

Water Planning Division
U.S. Environmental Protection Agency
Washington, D.C. 20460

i.a

DISCLAIMER

This report has been reviewed by the U.S. Environmental Protection Agency and approved for release. Approval does not signify that the contents necessarily reflect any policies or decisions of the U.S. Environmental Protection Agency or any of its offices, grantees, contractors, or subcontractors.

VOLUME I

TABLE OF CONTENTS

Chapter		Page
	Foreword	iii
	Preface	v
	Acknowledgements	vii
1	INTRODUCTION	1-1
2	BACKGROUND	2-1
	Early Perceptions	2-1
	Conclusions From Section 208 Efforts	2-2
	ORD Efforts	2-4
	Other Prior/Ongoing Efforts	2-5
	Discussion	2-5
	The Nationwide Urban Runoff Program	2-6
3	URBAN RUNOFF PERSPECTIVES	3-1
	Water Quantity Concerns	3-1
	Water Quality Concerns	3-2
	Water Quantity and Quality Control	3-3
	Problem Definition	3-4
4	METHOD OF ANALYSIS	4-1
	Introduction	4-1
	Urban Runoff Pollutant Loads	4-1
	Water Quality Effects	4-4
	Evaluation of Controls	4-13
	Quality Assurance and Quality Control	4-15
5	FINDINGS	5-1
	Introduction	5-1
	Loadings	5-2

TABLE OF CONTENTS (Cont'd)

Chapter Page

Receiving Water Effects 5-27
Evaluation of Controls 5-54
Project Findings 5-59

6 CONCLUSIONS TO DATE 6-1

7 REFERENCES 7-1

LIST OF FIGURES

Figure Page

5-1a Cumulative Probability Plots in Log-Space 5-5
5-1b Cumulative Probability Plots in Log-Space 5-6
5-2 Pollutant Concentration in Urban Runoff Event Means (Preliminary NURP Data - 13 Projects) 5-7
5-3 Comparison of NURP Results with Other Studies 5-10
5-4 Urban Runoff Concentration Ranges for NURP Pilot Data 5-12
5-5 Zonal Differences in Event Mean Concentrations 5-18
5-6 Contours of Long Term Storm Event Average Rainfall Intensity for the Period June-September 5-29
5-7 Regional Value of Average Annual Stream Flow 5-30
5-8 Schematic of Rapid City Stream System 5-33
5-9 Distribution of Lead Concentrations in Rapid City During Storm Runoff Periods (Preliminary Projection) 5-36
5-10 Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentration 5-37
5-11 Effect of Urban Runoff Control on Distribution of Lead Concentration in Streams 5-40
5-12 Effects of Urban Runoff Control on Lead Concentrations 5-41
5-13 Copper Concentration in Urban Runoff 5-43
5-14 Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - End-of-Pipe . . . 5-45

LIST OF FIGURES (Cont'd)

Figure | | Page
5-15 Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - DAR 10 5-46
5-16 Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - DAR 50 5-47
5-17 Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - DAR-100 5-48
5-18 Lead - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentration 5-50
5-19 Zinc - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentration 5-51
5-20 Cadmium - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentration 5-52
5-21 Chromium - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentration 5-53

LIST OF TABLES

Table | | Page
4-1 Summary of Receiving Water Target Concentrations Used in Screening Analysis - Toxic Substances 4-8
5-1 Sources of Data 5-4
5-2 Comparison of Preliminary NURP Data With Prior Summaries 5-8
5-3 Duncan's Multiple Range Test ($\alpha = 0.5$) 5-15
5-4 Data Set Attributes By Zone 5-16
5-5 Data as a Ratio of Total Population Median by Zone 5-17
5-6 Data as a Ratio of Total Population Median by Season 5-19
5-7 Data as a Ratio of Total Population Median by Rainfall 5-21
5-8 Data as a Ratio of Total Population Median by Land Use 5-22

LIST OF TABLES (Cont'd)

Table Page

5-9 Average Storm and Time Between Storms for Selected Locations in the U.S. 5-28

5-10 Percent Removal Effectiveness for the Traver Creek Detention Basin 5-55

5-11 Overall Percent Removal Effectiveness for Selected NURP Detention Basins 5-56

5-12 Percent Removal Effectiveness for Pooled Detention Basin Data 5-57

5-13 Summary of Lead Statistics for Winston-Salem NURP Project 5-58

5-14 Percent Removal Effectiveness for Pooled Street Sweeping Data 5-59

VOLUME II

TABLE OF CONTENTS

Appendix

A Selected Site Characteristics A-1

B Selected Event Data B-1

C Data Analysis Methodologies C-1

D Wet Weather Water Quality Criteria D-1

E Project Summaries E-1

F Priority Pollutant Report F-1

G Project Descriptions G-1

H ORD Report H-1

APPENDIX A

SELECTED SITE CHARACTERISTICS

APPENDIX A
FOREWORD

This appendix contains selected monitoring site characteristics data for those projects that were included in the data analysis up to this point. Referred to as Fixed Site Data, the information selected for inclusion in this appendix is analyzed in columns as follows:

PROJECT

Code - A unique alphanumeric code number that identifies each of the 28 NURP projects in the NURP STORET data base (see listing that follows).

Name - The urban area in which the NURP project is located.

CATCHMENT

Code - A unique alphanumeric code number assigned by individual NURP projects to each monitoring site used, as entered in the NURP STORET data base.

Name - The name by which the monitoring site is known within each project.

AREA

The size of the contributing drainage area at the monitoring site; expressed in acres (multiply by 0.4047 to obtain hectares).

LAND USE

The percentage of the total drainage area that is predominantely used as residential, commercial, industrial, or parkland/open (see listing that follows).

POPULATION DENSITY

The population density in the catchment calculated by dividing the total population residing within the contributing drainage basin by its area in acres; expressed as persons per acre (multiply by 2.471 to obtain persons per hectare).

SLOPE

A measure of the representative catchment slope; expressed in feet per mile (multiply by 0.0001893 to obtain percent).

2

NATIONWIDE URBAN RUNOFF PROJECT LOCATIONS

NURP PROJECTS

1.DURHAM, NEW HAMPSHIRE	NH1
2.LAKE QUINSIGAMOND, MASSACHUSETTS	MA1
3.MYSTIC RIVER, MASSACHUSETTS	MA2
4.LONG ISLAND, NEW YORK	NY1
5.LAKE GEORGE, NEW YORK	NY2
6.IRONDEQUOIT BAY, NEW YORK	NY3
7.METRO WASHINGTON, D.C.	DC1
8.BALTIMORE, MARYLAND	MD1
9.MYRTLE BEACH, SOUTH CAROLINA	SC1
10.WINSTON-SALEM, NORTH CAROLINA	NC1
11.TAMPA, FLORIDA	FL1
12.KNOXVILLE, TENNESSEE	TN1
13.LANSING, MICHIGAN	MI1
14.OAKLAND COUNTY, MICHIGAN	MI2
15.ANN ARBOR, MICHIGAN	MI3
16.CHAMPAIGN-URBANA, ILLINOIS	IL1
17.CHICAGO, ILLINOIS	IL2
18.MILWAUKEE, WISCONSIN	WI1
19.AUSTIN, TEXAS	TX1
20.LITTLE ROCK, ARKANSAS	AR1
21.KANSAS CITY, KANSAS	KS1
22.DENVER, COLORADO	CO1
23.SALT LAKE CITY, UTAH	UT1
24.RAPID CITY, SOUTH DAKOTA	SD1
25.CASTRO VALLEY, CALIFORNIA	CA1
26.FRESNO, CALIFORNIA	CA2
27.BELLEVUE, WASHINGTON	WA1
28.EUGENE, OREGON	OR1

NON-NURP PROJECTS

29.MINNEAPOLIS, MINNESOTA	MN1
30.DES MOINES, IOWA	IA1
31.TOPEKA, KANSAS	KS2
32.RENO, NEVADA	NV1
33.SALEM, OREGON	OR2
34.DALLAS, TEXAS	TX2

LAND USE CODES

URBAN RESIDENTIAL (<.5 DWELLING UNITS/ACRE)	1110	1100
URBAN RESIDENTIAL (.5 TO 2 DWELLING UNITS/ACRE)	1120	
URBAN RESIDENTIAL (2.5 TO 8 DWELLING UNITS/ACRE)	1130	
URBAN RESIDENTIAL (>8 DWELLING UNITS/ACRE)	1140	
URBAN COMMERCIAL (CENTRAL BUSINESS DISTRICT)	1201	1200
URBAN COMMERCIAL (LINEAR STRIP DEVELOPMENT)	1202	
URBAN COMMERCIAL (SHOPPING CENTER)	1203	
URBAN INDUSTRIAL (LIGHT)	1301	1300
URBAN INDUSTRIAL (MODERATE)	1302	
URBAN INDUSTRIAL (HEAVY)	1303	
URBAN PARKLAND OR OPEN SPACE	1400	1400
URBAN INSTITUTIONAL	1401	
URBAN UNDER CONSTRUCTION	1500	
AGRICULTURE	2000	
RANGELAND	3000	
FOREST	4000	
WATER, STREAMS AND CANALS	5100	
WATER, LAKES	5200	
WATER, RESERVOIRS	5300	
WATER, BAYS AND ESTUARIES	5400	
WATER, OCEANS	5500	
WETLANDS	6000	
BARREN	7000	

NATIONWIDE URBAN RUNOFF PROGRAM
FIXED-SITE DATA FOR FASTTRACK FILE

PROJECT		CATCHMENT		AREA	LANDUSE DISTRIBUTION (% OF TOTAL AREA)					POP/DEN	CATCHMENT
CODE	NAME	CODE	NAME	AC	1100	1200	1300	1400	Other	PER/AC	SLOPE FT/MI
NH 1	Durham	1 PKG	Parking Lot	.9	-	100	-	-	-	0	58.
MA 1	Lake Q.	P1	Jordon P	110	78	16	4	2	-	N.D.	N.D.
		P2	Rte 9	338	47	24	11	18	-	N.D.	N.D.
		P3	Locust Ave.	154	85	1	8	5	-	N.D.	N.D.
		P4	Guua St.	601	66	2	1	31	-	N.D.	N.D.
		P5	Convent	100	8	63	0	29	-	N.D.	N.D.
		P6	Tilly Br.	1690	20	7	2	58	12 Wdland	N.D.	N.D.
DC 1	WASH COG	001	St.W.D.	8.46	100	-	-	-	-	N.D.	84.5
		002	Duf	11.84	100	-	-	-	-	N.D.	450
		003	Weh R.P.	47.9	84	-	-	16	-	N.D.	195
		004	F.R. Rd Se.	18.8	88	-	-	12	-	N.D.	227
		006	Stdw DP	34.4	66	-	-	34	-	N.D.	248
		007	Lake DP	97.8	54	-	-	46	-	N.D.	420
		008	Danrge I.T.	1.96	100	-	-	-	-	N.D.	190
		009	Rocky CCPP	4.2	-	-	-	100	-	N.D.	135
		010	Bulk Mail	20.1	-	-	-	100	-	N.D.	N.D.
		011	Burke V.	4.5	82	-	-	18	-	N.D.	85
		103	Westly RP.	40.95	92	-	-	8	-	N.D.	195
		106	Sted. DP	27.4	78	-	-	22	-	N.D.	248
		107	Lake DP	77.7	54	-	-	46	-	N.D.	420
		110	Bulk Mail	19	54	-	-	46	-	N.D.	N.D.
NC 1	Win. Slm.	NC1013	C.B.D.	23	0	100	0	0	-	N.D.	N.D.
		NC1023	Ardmore	324	84	2	-	12	-	N.D.	N.D.
IL 1	Champaign	B01	Mattis N	16.66	43	57	-	-	-	3.0	187
		B02	Mattis S.	27.6	90	10	-	-	-	21.74	549
		B03	J & D	1.38	100	-	-	-	-	21.7	90.0
		B04	John St. S.	39.2	90	-	-	10	-	18.37	62
		B05	John N.	54	100	-	-	-	-	18.38	30.6
IL 2	G. Ellyn	001	Lake Ellyn	534	83	5	-	12	-	7.87	49
MI 1	Lansing	001	B.S.D.	452.6	48	5	19	28	-	4.97	221
		002	B.S.D.	63	-	-	100	-	-	0	132
		DRO	B.S.D.	127.6	46	14	-	40	-	4.31	121

NATIONWIDE URBAN RUNOFF PROGRAM
FIXED-SITE DATA FOR FASTTRACK FILE (CONT'D)

PROJECT		CATCHMENT		AREA	LANDUSE DISTRIBUTION (% OF TOTAL AREA)					POP/DEN	CATCHMENT
CODE	NAME	CODE	NAME	AC	1100	1200	1300	1400	Other	PER/AC	SLOPE FT/MI
MI 1	Lansing (CONTINUED)	DRI	B.S.D.	112.7	38	16	-	46	-	4.26	233
		GCO	B.S.D.	67	30	15	-	55	-	5.07	200
		GCI	B.S.D.	30.3	67	33	-	-	-	5.07	121
		UPI	B.S.D.	163.9	55	-	10	35	-	5.19	226
		UP2	B.S.D.	74.9	48	-	22	40	-	4.94	194
MI 3	Ann Arbor	001	Pitt AA(1)S	2001	31	23	7	24	15	1.9	33.8
		002	Pitt AA(RB)N	2871	55	10	3	21	11	6.54	60.7
		003	Pitt AA(RB)O	4872	45	15	4	23	13	4.64	45.5
		004	Pitt S-AARO	6363	48	14	3	25	10	4.35	61.6
		005	SR Wetld INT.	1207	53	1	1	15	30	2.24	32.1
		006	SR Wetld OOT.	1227	53	1	1	15	30	2.24	32.1
		007	Swift Run ORO	3075	50	4	1	33	12	3.51	39.6
		008	Traver CKO	4402	15	1	2	35	47	1.91	58.6
		009	Traver CK RBI	2303	8	-	2	-	90	.07	33.2
		010	Traver CK RBO	2327	8	-	2	1	89	.07	33.2
		011	NCampus DOR	1541	46	16	-	38	-	1.82	89.8
		012	Allen DR OTR	3800	58	9	2	31	-	9.39	82.0
WI 1	Milwaukee	630	St. Fair	29	26	74	-	-	-	10.	160.
		631	Wood CTR.	44.9	31	56	13	-	-	.03	160.
		632	N. Hastings	32.84	100	-	-	-	-	17.05	
		633	N. Burbank	62.6	100	-	-	-	-	14.62	
		634	Rustler	12.44	100	-	-	-	-	0	
		635	Post Off.	12.08	-	100	-	-	-	0	
		636	Lincbler Cr.	36.1	97	3	-	-	-	18.01	
		637	West Congress	33.04	93	7	-	-	-	16.34	
TX 1	Austin	001	Northwest	377.71	99	1	-	-	-	9.27	237.6
		002	Rolling wd	60.21	100	-	-	-	-	3.32	260
		003	Turkey Ck	1297	4	-	-	96	-	.05	396.0
CO 1	Denver	001	50th & Den	119900	43	13	6	38	-	4.85	248.
		002	19th & Den	108329	42	12	5	40	-	4.29	261
		003	Cherry Ck.	15817	42	16	5	38	-	6.22	183
		004	Lake Den	10440	55	23	2	20	-	4.83	316

NATIONWIDE URBAN RUNOFF PROGRAM
FIXED-SITE DATA FOR FASTTRACK FILE (CONT'D)

PROJECT		CATCHMENT		AREA	LANDUSE DISTRIBUTION (% OF TOTAL AREA)					POP/DEN	CATCHMENT
CODE	NAME	CODE	NAME	AC	1100	1200	1300	1400	Other	PER/AC	SLOPE FT/MI
CO 1	Denver (CONTINUED)	005	Weir Gulch	4786	64	10	1	25	-	7.64	240
		006	Sandrsn G	4715	66	13	2	19	-	9.57	168
		007	Hrvd G.	2833	72	16	1	11	-	7.72	143
		008	Bear Ck.	14603	34	9	2	10	-	2.91	444
		009	SoPlat Lit.	N.D.	-	-	-	-	Const. 45	N.D.	N.D.
WA 1	Bellevue	001	Lake Hills	101.7	90	-	-	10	-	11.7	317
		002	Surry Downs	95.1	100	-	-	-	-	8.64	475
SD 1	Rapid City	001	RpdCk Abv CLake	33574	4	-	-	-	96 Forest	N.D.	N.D.
		002	RpdCk Abv WTP	20877	16	-	-	5	79	N.D.	N.D.
		003	RpdCk AtRpd Cty	3872	2	13	5	20	60	N.D.	N.D.
		004	RpdCk AtE MnSt	3540	36	14	-	15	35	N.D.	N.D.
		005	RpdCk BloHtnDh	1606	20	26	-	35	19	N.D.	N.D.
		006	MeideDnRpdCty	1760	55	7	-	14	24	N.D.	N.D.

APPENDIX B

SELECTED EVENT DATA

8

```
                                                    FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   52
     FAST-TRACK DATA                    PROJECT   NC1       SITEID    02479550

     EVENT                              PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
     START                              (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
     TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


     03/17/80                           1.03           97             .              .              .              .
     03/24/80                           1.13           .              25             0.11           0.05           0.02
     04/08/80                           0.28           .              94             0.25           0.338          0.065
     04/24/80                           0.25           146            182            0.55           0.258          0.078
     04/29/80                           0.18           .              133            0.21           0.275          0.063
     05/14/80                           0.57           296            600            1.95           1.687          0.195
     05/19/80                           0.25           107            46             0.78           0.211          0.035
     08/21/80                           0.53           .              91             0.24           0.181          0.065
     09/29/80                           0.78           .              2380           0.4            0.138          0.073
     10/28/80                           1.21           .              282            0.21           0.319          0.067
     11/08/80                           0.8            .              37             0.22           0.111          0.036
     11/17/80                           0.71           .              83             0.17           0.154          0.032
     12/09/80                           0.29           42             18             0.17           0.146          0.057
     01/21/81                           0.19           .              130            0.78           0.722          0.117
     02/02/81                           0.51           .              232            0.4            0.751          0.09
     02/07/81                           0.09           .              74             0.46           1.01           0.075
     02/10/81                           1.29           81             77             0.3            0.75           0.062
     02/18/81                           1.23           28             53             0.2            0.279          0.077
     03/06/81                           0.74           86             78             0.26           0.279          0.034
     03/30/81                           1.11           60             302            0.38           0.68           0.075
     04/30/81                           0.12           377            330            0.98           1.074          0.157
 SITE MEAN                              0.6788349      135.378        229.483        0.4310559      0.4886075      0.07431119
 SITE COEFFICIENT OF VARIATION          0.9846602      0.9896254      1.631983       0.7861554      1.110038       0.5862896

 NUMBER OF EVENTS FOR THIS STATION       21



                                                    FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   53
     FAST-TRACK DATA                    PROJECT   NC1       SITEID    02485000

     EVENT                              PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
     START                              (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
     TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


     03/17/80                           1              128            .              .              .              .
     04/24/80                           0.28           .              .              .              .              .
     04/29/80                           0.18           .              80             0.4            0.138          0.023
     05/14/80                           0.56           268            1028           1.71           0.894          0.081
     06/29/80                           0.19           .              581            0.88           0.465          0.036
     07/09/80                           1.25           .              566            0.73           0.506          0.032
     07/10/80                           0.64           .              155            0.32           0.26           0.03
     07/12/80                           0.4            .              188            0.31           0.349          0.021
     07/12/80                           1.05           .              453            0.8            0.476          0.039
     08/21/80                           0.92           .              569            0.92           0.467          0.051
     08/22/80                           0.75           .              782            1.02           0.659          0.088
     09/24/80                           4.13           .              544            0.73           0.212          0.036
     09/29/80                           0.88           .              81             0.17           0.122          0.02
     10/24/80                           1.16           .              127            0.34           0.092          0.024
     10/28/80                           0.13           .              12             0.1            0.051          0.017
     11/04/80                           0.74           .              76             0.24           0.117          0.024
     11/15/80                           0.32           .              13             0.34           0.072          0.02
     11/17/80                           1.03           .              58             0.34           0.089          0.021
     11/24/80                           0.89           .              106            0.4            0.118          0.019
     12/09/80                           0.28           .              14             0.23           0.069          0.02
     01/21/81                           0.19           .              36             0.28           0.1            0.017
     03/04/81                           0.78           38             46             0.18           0.157          0.069
     03/30/81                           2.31           59             388            0.83           0.359          0.043
     04/30/81                           0.23           322            698            1.8            0.739          0.084
 SITE MEAN                              0.8567582      183.428        393.3252       0.6042713      0.3062436      0.03680769
 SITE COEFFICIENT OF VARIATION          1.050464       1.164093       2.588073       0.8849981      1.069615       0.5831115

 NUMBER OF EVENTS FOR THIS STATION       24
```

9

```
                                    FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   54

FAST-TRACK DATA                 PROJECT   C01       SITEID    06710225

EVENT                       PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
START                       (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
TIME                                       PER LITER      PER LITER      PER LITER      PER LITER      PER LITER



05/15/80                    0.65           92             247            0.51           0.179          0.018
05/17/80                    0.39           59             197            0.46           0.184          0.014
07/01/80                    0.27           170            1070           1              0.18           0.05
05/03/81                    0.22           300            256            1.6            0.46           0.08
05/03/81                    0.38           340            988            0.94           0.46           0.1
05/09/81                    0.21           86             205            0.4            0.077          0.02
05/12/81                    0.29           68             135            0.29           0.066          0.016
07/17/81                    0.59           78             243            0.5            0.1            0.025

SITE MEAN                   0.3784279      151.2115       417.2345       0.7218595      0.2079746      0.03126308
SITE COEFFICIENT OF VARIATION 0.4426575    0.7671075      0.8913725      0.6145716      0.874869       0.8925991

NUMBER OF EVENTS FOR THIS STATION      8



                                    FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   55

FAST-TRACK DATA                 PROJECT   C01       SITEID    06710610

EVENT                       PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
START                       (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
TIME                                       PER LITER      PER LITER      PER LITER      PER LITER      PER LITER



04/23/80                    1.77           71             463            0.53           0.04           0.018
04/30/80                    1.97           71             562            0.15           0.025          0.019
05/08/80                    0.25           66             190            0.085          0.15           0.012
05/15/80                    0.59           52             256            0.27           0.022          0.012
05/16/80                    0.48           42             204            0.21           0.017          0.01
05/17/80                    0.91           32             85             0.14           0.008          0.01

SITE MEAN                   1.069648       56.32011       309.5773       0.2367029      0.04886426     0.01357642
SITE COEFFICIENT OF VARIATION 0.9392044    0.3336561      0.7673779      0.6968631      1.276301       0.2887182

NUMBER OF EVENTS FOR THIS STATION      6



                                    FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   56

FAST-TRACK DATA                 PROJECT   C01       SITEID    06711585

EVENT                       PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
START                       (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
TIME                                       PER LITER      PER LITER      PER LITER      PER LITER      PER LITER



05/03/80                    0.31           310            788            1.2            0.43           0.09
06/14/80                    0.59           162            711            1.28           0.406          0.082
05/03/81                    0.23           410            232            2.6            0.88           0.13

SITE MEAN                   0.3905218      307.0165       637.5879       1.739467       0.572228       0.09316719
SITE COEFFICIENT OF VARIATION 0.5107312    0.504716       0.7647421      0.4495004      0.4212895      0.6276217

NUMBER OF EVENTS FOR THIS STATION      3
```

```
                                               FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   57

     FAST-TRACK DATA                   PROJECT   C01       SITEID    06711635

     EVENT                          PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
     START                          (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
     TIME                                          PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


     05/08/80                       0.24           115            659            0.69           0.22           0.5
     05/11/80                       0.07           159            358            0.36           0.204          0.03
     05/12/80                       0.03           164            567            0.48           0.224          0.041
     05/15/80                       0.52           81             338            0.38           0.148          0.028
     05/17/80                       0.28           130            432            0.43           0.24           0.033
     07/24/80                       0.13           300            492            1.7            0.46           0.058
     08/10/80                       0.05           640            564            0.8            0.45           0.058
     09/08/80                       0.74           142            210            0.39           0.136          0.026
     09/10/80                       0.08           170            128            0.24           0.096          0.017
     09/10/80                       0.15           293            735            0.79           0.341          0.042
     03/03/81                       0.17           310            380            0.57           0.45           0.05
     05/03/81                       0.22           280            .              0.61           0.34           0.16
     05/05/81                       0.08           460            568            1.8            0.43           0.09
     05/09/81                       0.38           100            215            0.43           0.17           0.033
     05/16/81                       0.14           240            358            0.69           0.27           0.06
     05/17/81                       0.78           79             184            0.3            0.08           0.024
     05/28/81                       0.04           240            548            0.66           0.26           0.085
     05/28/81                       0.22           160            392            0.53           0.19           0.055
     07/02/81                       0.12           300            440            0.51           0.27           0.056

 SITE MEAN                          0.2424144      230.9788       427.2367       0.6422348      0.266499       0.06877531
 SITE COEFFICIENT OF VARIATION      1.170946       0.6181283      0.5031408      0.554211       0.5420354      0.89049

 NUMBER OF EVENTS FOR THIS STATION      19
```

```
                                               FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   58

     FAST-TRACK DATA                   PROJECT   C01       SITEID    06713010

     EVENT                          PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
     START                          (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
     TIME                                          PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


     08/14/80                       0.69           88             94             0.4            0.159          0.014
     05/12/81                       0.28           40             30             0.23           0.039          0.008
     05/28/81                       0.18           180            508            0.65           0.54           0.04
     07/12/81                       0.62           88             148            0.37           0.16           0.016

 SITE MEAN                          0.4716985      104.3621       239.2789       0.4221909      0.2709215      0.02044296
 SITE COEFFICIENT OF VARIATION      0.7178299      0.6772068      1.712337       0.4453097      1.473436       0.748959

 NUMBER OF EVENTS FOR THIS STATION      4
```

```
                                               FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   59

     FAST-TRACK DATA                   PROJECT   C01       SITEID    06720420

     EVENT                          PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
     START                          (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
     TIME                                          PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


     05/07/80                       0.81           60             158            0.34           0.111          0.01
     07/01/80                       0.19           170            200            0.63           0.15           0.018
     07/02/80                       0.38           255            613            0.96           0.744          0.044
     08/15/80                       0.37           100            123            0.71           0.26           0.035
     08/25/80                       0.24           116            111            0.63           0.141          0.016
     08/26/80                       0.34           104            108            0.52           0.19           0.02

 SITE MEAN                          0.3931642      136.7557       217.0828       0.6395516      0.2654751      0.02443413
 SITE COEFFICIENT OF VARIATION      0.5281268      0.5267523      0.7359692      0.3561129      0.7713025      0.5819626

 NUMBER OF EVENTS FOR THIS STATION      6
```

```
                                         FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   60

   FAST-TRACK DATA                 PROJECT  CO1       SITEID    390236105042600

   EVENT                           PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
   START                           (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
   TIME                                           PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


   07/01/80                        0.44           157           114           0.3           0.167         0.021
   07/11/80                        0.13           290           192           0.43          0.31          0.03
   07/30/80                        0.06           640           184           1.3           0.5           0.075
   08/07/80                        0.07           93            278           1.15          0.633         0.055
   08/10/80                        0.04           470           192           0.71          0.32          0.085
   08/14/80                        1.99           68            133           0.22          0.16          0.016
   08/25/80                        0.34           96            57            0.27          0.102         0.012
   09/08/80                        0.05           480           272           0.77          0.33          0.05
   09/08/80                        0.72           81            28            0.19          0.049         0.014
   09/10/80                        0.08           110           14            0.15          0.046         0.009

SITE MEAN                          0.4019668      252.1817      175.5931      0.567877      0.2890032     0.03399142
SITE COEFFICIENT OF VARIATION      2.161956       0.9994623     1.326933      0.9011743     1.138593      0.8817196

NUMBER OF EVENTS FOR THIS STATION      10
```

```
                                         FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   61

   FAST-TRACK DATA                 PROJECT  DC1       SITEID    DC1SIUR03

   EVENT                           PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
   START                           (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
   TIME                                           PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


   11/04/80                        .              16            13            0.29          .             .
   11/09/80                        .              56            154           0.26          .             .
   11/25/80                        0.63           17            8             0.2           .             .
   11/29/80                        0.31           8             1             0.1           .             .
   12/09/80                        0.2            40            21            0.12          .             .
   12/23/80                        0.13           32            6             0.17          .             .
   02/20/81                        0.33           40            39            .             .             .
   02/21/81                        0.06           36            23            0.06          .             .
   02/22/81                        0.15           46            19            1.86          .             .
   02/22/81                        1.3            20            17            0.11          .             .
   03/04/81                        0.45           .             18            0.16          .             .
   03/16/81                        0.14           33            22            0.65          .             .
   03/30/81                        0.98           52            102           0.28          .             .
   03/31/81                        0.14           25            11            0.12          .             .

SITE MEAN                          0.4155559      34.52076      36.2776       0.3043352     .             .
SITE COEFFICIENT OF VARIATION      1.149514       0.8372978     1.811169      1.096979      .             .

NUMBER OF EVENTS FOR THIS STATION      14
```

```
                                         FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   62

   FAST-TRACK DATA                 PROJECT  DC1       SITEID    DC1SIUR05

   EVENT                           PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
   START                           (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
   TIME                                           PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


   09/17/80                        0.31           41            12            0.34          .             .
   09/25/80                        .              36            6             0.27          .             .
   11/04/80                        .              20            12            1.38          .             .
   11/09/80                        .              60            152           0.36          .             .
   11/16/80                        0.9            60            9             0.28          .             .
   11/27/80                        0.21           19            3             0.39          .             .
   12/09/80                        0.2            46            22            0.23          .             .
   02/02/81                        0.84           56            48            1.46          .             .
   02/08/81                        0.31           56            28            1.12          .             .
   02/10/81                        0.85           55            43            1.1           .             .
   02/19/81                        0.49           52            20            0.57          .             .
   02/20/81                        0.2            54            23            0.34          .             .
   02/22/81                        1.14           58            19            0.56          .             .
   03/04/81                        0.59           .             6             0.38          .             .
   03/16/81                        0.28           65            10            0.22          .             .
   03/30/81                        0.38           72            37            0.34          .             .

SITE MEAN                          0.5236732      49.1793       27.31947      0.578809      .             .
SITE COEFFICIENT OF VARIATION      0.6857102      0.398802      1.213859      0.7225627     .             .

NUMBER OF EVENTS FOR THIS STATION      16
```

```
                                              FASTTRACK LOAD DATA                              16:18 MONDAY, JANUARY 4, 1982   63
 FAST-TRACK DATA                    PROJECT   DC1        SITEID    DC151UR06

 EVENT                            PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
 START                            (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
 TIME                                            PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


 10/25/80                         .              46             48             0.61           .
 11/17/80                         1              42             63             0.31           .              .
 11/24/80                         1.3            12             52             .              .              .
 11/27/80                         0.3            10             15             0.15           .              .
 02/02/81                         0.85           96             221            0.72           .              .
 02/02/81                         0.82           .              10             .              .              .
 02/08/81                         0.26           71             65             .              .              .
 02/11/81                         0.9            62             119            0.46           .              .
 02/19/81                         0.73           60             49             0.14           .              .
 02/20/81                         0.07           48             31             0.12           .              .
 02/22/81                         0.54           50             72             0.2            .              .
 03/05/81                         5.44           .              25             0.18           .              .
                                                                                             .              .
SITE MEAN                         0.7384666      54.15582       67.05911       0.327427       .
SITE COEFFICIENT OF VARIATION     1.003429       0.8528895      1.026941       0.7549802      .              .
                                                                                             .              .
NUMBER OF EVENTS FOR THIS STATION      12



                                              FASTTRACK LOAD DATA                              16:18 MONDAY, JANUARY 4, 1982   64
 FAST-TRACK DATA                    PROJECT   DC1        SITEID    DC151UR07

 EVENT                            PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
 START                            (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
 TIME                                            PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


 07/22/80                         0.32           36             247            0.21           .
 07/23/80                         0.11           47             424            0.26           .              .
 07/29/80                         0.1            61             66             0.11           .              .
 08/01/80                         0.67           .              116            0.24           .              .
 08/03/80                         0.21           .              120            0.27           .              .
 08/04/80                         0.66           78             144            0.22           .              .
 08/18/80                         0.42           140            825            0.94           .              .
 08/19/80                         0.17           33             99             0.14           .              .
 09/10/80                         0.11           132            294            0.5            .              .
 10/02/80                         0.51           .              230            .              .              .
 10/25/80                         2.25           40             514            0.7            .              .
 10/28/80                         0.04           22             25             0.08           .              .
 11/04/80                         0.28           28             16             0.29           .              .
 11/24/80                         0.78           64             66             0.23           .              .
 11/27/80                         0.37           12             28             0.12           .              .
                                                                                             .              .
SITE MEAN                         0.4883155      59.11295       243.0666       0.3088217      .
SITE COEFFICIENT OF VARIATION     1.341025       0.8101985      1.663697       0.7829968      .              .
                                                                                             .              .
NUMBER OF EVENTS FOR THIS STATION      15



                                              LFILE(STORET) LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   12
 LFILE (STORET) DATA

                                    PROJECT   220CCITY                       SITEID        DC151UR09

 EVENT                            BOD            COD            TSS            PHOSPHORUS     LEAD           COPPER
 START                            MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
 TIME                                            PER LITER      PER LITER      PER LITER      PER LITER      PER LITER
                                  310            80116          530            665            1051           1042


 10/02/80                         .              92.59999       4              .              0.1            0.02
 10/25/80                         3.299999       138            21             1.349999       0.12           0.02
 11/08/80                         .              24             0              0.35           0.1            0.02
 11/17/80                         .              24             4              0.5599999      0.1            0.02
 11/24/80                         .              22.31407       6              0.4380716      0.1            0.02
 11/27/80                         .              36             3.5            0.14           0.1            0.02
 12/09/80                         .              60             9              0.09999996     0.1            0.02
 12/16/80                         .              68             11             .              0.1            0.02
 12/23/80                         .              .              72             .              0.1            0.02
 02/02/81                         10             48             50             0.32           0.1            0.065
 02/08/81                         .              47             13             0.3            0.1            0.02
 02/11/81                         4.2            61             13             0.32           0.1            0.02
 02/19/81                         .              52.01957       10.53929       0.08978619     0.1            0.02
 03/30/81                         .              44             6              0.11           0.1            0.02
SITE MEAN                         6.134019       55.59342       16.66666       0.3775807      0.1014313      0.02286345
SITE COEFFICIENT OF VARIATION     0.6363271      0.574268       1.176921       0.9996451      0.04875641     0.3229873

NUMBER OF EVENTS FOR THIS STATION      14
```

13

```
                                                 FASTTRACK LOAD DATA                       16:18 MONDAY, JANUARY 4, 1982   65

    FAST-TRACK DATA                    PROJECT   DC1        SITEID    DC151UR10

    EVENT                              PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
    START                              (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
    TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


    10/18/80                           .              62             45             0.33           .              .
    10/25/80                           .              26             19             0.6            .              .
    10/25/80                           .              58             42             0.31           .              .
    11/17/80                           1.25           22             18             0.44           .              .
    11/24/80                           1.5            8              68             0.44           .              .
    12/09/80                           0.2            60             33             .              .              .
    02/02/81                           1.21           60             145            1.55           .              .
    02/08/81                           0.29           72             49             0.93           .              .
    02/19/81                           0.55           80             37             0.65           .              .
    02/20/81                           0.37           40             34             0.17           .              .
    02/22/81                           0.87           56             21             0.17           .              .
    03/16/81                           0.22           18             44             .              .              .

SITE MEAN                              0.7579506      49.79799       45.96096       0.5715887      .              .
SITE COEFFICIENT OF VARIATION          0.9284045      0.7881695      0.6298863      0.7946728      .              .

NUMBER OF EVENTS FOR THIS STATION      12


                                                 FASTTRACK LOAD DATA                       16:18 MONDAY, JANUARY 4, 1982   66

    FAST-TRACK DATA                    PROJECT   DC1        SITEID    DC151UR15

    EVENT                              PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
    START                              (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
    TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


    12/09/80                           0.2            48             36             0.26           .              .
    01/21/81                           0.16           .              404            0.73           .              .
    02/02/81                           0.28           76             604            0.95           .              .
    02/08/81                           0.8            63             171            0.55           .              .
    02/19/81                           1.27           40             149            0.24           .              .
    02/20/81                           0.9            36             68             0.2            .              .
    02/21/81                           0.09           56             21             0.24           .              .
    02/22/81                           0.39           40             55             0.23           .              .
    03/04/81                           0.6            20             27             0.33           .              .

SITE MEAN                              0.565756       47.62288       185.3837       0.4163227      .              .
SITE COEFFICIENT OF VARIATION          1.093316       0.4256678      1.763121       0.6206362      .              .

NUMBER OF EVENTS FOR THIS STATION      9


                                                 LFILE(STORET) LOAD DATA                   16:18 MONDAY, JANUARY 4, 1982   14

    LFILE (STORET) DATA
                                       PROJECT   220CCITY                   SITEID         DC151UR18

    EVENT                              BOD            COD            TSS            PHOSPHORUS     LEAD           COPPER
    START                              MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
    TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER
                                       310            80116          530            665            1051           1042


    02/08/81                           .              .              76             .              0.1            0.035
    02/23/81                           .              48             19             .              0.1            0.02

SITE MEAN                              .              .              61.43849       .              0.1000002      0.02861225
SITE COEFFICIENT OF VARIATION          .              .              1.270457       .              0              0.4117159

NUMBER OF EVENTS FOR THIS STATION      2
```

```
                                   LFILE(STORET) LOAD DATA              16:18 MONDAY, JANUARY 4, 1982   15

   LFILE (STORET) DATA
                                PROJECT   22ILCITY              SITEID        BASIN1

   EVENT                     BOD          COD          TSS          PHOSPHORUS   LEAD         COPPER
   START                     MILLIGRAMS   MILLIGRAMS   MILLIGRAMS   MILLIGRAMS   MILLIGRAMS   MILLIGRAMS
   TIME                                   PER LITER    PER LITER    PER LITER    PER LITER    PER LITER
                             .            340          530          .            1051         1042



   01/11/80                  .            287.1818     473.6273     .            1.865788     0.0686842
   01/16/80                  .            .            235.8778     .            4.366665     0.1433333
   03/07/80                  .            233.2335     181.0282     .            1.447552     0.05780216
   03/16/80                  .            477.7659     116.6552     .            0.809779     0.03261484
   03/24/80                  .            .            70.34807     .            0.3724004    0.01241249
   03/28/80                  .            .            145.7861     .            .            .
   03/30/80                  .            .            40.08828     .            .            .
   04/03/80                  .            307.0111     221.7532     .            1.097494     0.03039871
   04/08/80                  .            .            102.1728     .            .            .
   05/12/80                  .            219.3068     97.95041     .            0.6646952    0.05672838
   05/12/80                  .            .            80.77591     .            .            .
   05/16/80                  .            .            223.275      .            .            .
   05/17/80                  .            .            198.1078     .            .            .
   05/23/80                  .            .            162.8839     .            .            .
   06/01/80                  .            .            95.62083     .            .            .
   06/15/80                  .            132.2693     .            .            0.3208717    0.01626562
   06/15/80                  .            216.1258     .            .            0.7885989    0.03068793
   06/23/80                  .            .            129.7858     .            .            .
   06/28/80                  .            .            116.9721     .            .            .
   07/26/80                  .            616.9002     .            .            0.6027931    0.0505903
   07/27/80                  .            128.2567     .            .            0.438074     0.01708577

SITE MEAN                    .            294.4682     159.3277     .            1.145438     0.08785276
SITE COEFFICIENT OF VARIATION .           0.5602676    0.6131393    .            0.8967704    0.8305187

NUMBER OF EVENTS FOR THIS STATION      21
```

```
                                   LFILE(STORET) LOAD DATA              16:18 MONDAY, JANUARY 4, 1982   16

   LFILE (STORET) DATA
                                PROJECT   22ILCITY              SITEID        BASIN2

   EVENT                     BOD          COD          TSS          PHOSPHORUS   LEAD         COPPER
   START                     MILLIGRAMS   MILLIGRAMS   MILLIGRAMS   MILLIGRAMS   MILLIGRAMS   MILLIGRAMS
   TIME                                   PER LITER    PER LITER    PER LITER    PER LITER    PER LITER
                             .            340          530          .            1051         1042



   01/11/80                  .            112.3333     355.7179     .            0.7666664    0.1288888
   01/16/80                  .            .            382.3171     .            .            .
   03/07/80                  .            316.887      208.5218     .            0.329468     0.1360971
   03/16/80                  .            446.0503     85.97689     .            0.7534172    0.02341742
   03/24/80                  .            .            68.08028     .            .            .
   03/28/80                  .            .            132.4064     .            .            .
   04/03/80                  .            236.6899     256.7868     .            0.7120225    0.03114598
   05/12/80                  .            200.0308     70.29839     .            0.8727856    0.0533569
   05/12/80                  .            171.2029     .            .            0.5792718    0.02896844
   05/17/80                  .            .            100.9898     .            .            .
   05/17/80                  .            .            79.30837     .            .            .
   05/23/80                  .            .            129.0968     .            .            .
   05/30/80                  .            142.6512     143.6533     .            0.8567193    0.04420955
   06/01/80                  .            .            99.03628     .            .            .
   06/15/80                  .            138.6606     .            .            0.3185815    0.02179649
   06/15/80                  .            227.5371     .            .            0.5640931    0.01888309
   06/23/80                  .            .            71.54267     .            .            .
   06/28/80                  .            .            116.2083     .            .            .

SITE MEAN                    .            222.7416     152.6209     .            0.7538844    0.03379893
SITE COEFFICIENT OF VARIATION .           0.4587546    0.6230581    .            0.4043906    0.3647516

NUMBER OF EVENTS FOR THIS STATION      18
```

Reproduced from
best available copy.

```
                                          LFILE(STORET) LOAD DATA              16:18 MONDAY, JANUARY 4, 1982   17

   LFILE (STORET) DATA
                                  PROJECT   22ILCITY              SITEID        BASIN3

   EVENT                         BOD              COD              TSS              PHOSPHORUS       LEAD             COPPER
   START                         MILLIGRAMS       MILLIGRAMS       MILLIGRAMS       MILLIGRAMS       MILLIGRAMS       MILLIGRAMS
   TIME                                           PER LITER        PER LITER        PER LITER        PER LITER        PER LITER
                                 .                340              530              .                1051             1042



   01/16/80                      .                .                252.4167         .                .                .
   03/16/80                      .                32.6747          158.6055         .                0.1493661        0.009999997
   05/12/80                      .                .                89.57392         .                .                .
   05/12/80                      .                .                51.47316         .                .                .
   05/17/80                      .                .                51.34498         .                .                .
   05/17/80                      .                .                43.29557         .                .                .
   05/19/80                      .                .                59.38892         .                .                .
   05/23/80                      .                .                49.82009         .                .                .
   05/30/80                      .                70.4974          .                .                0.2606739        0.02487793
   06/01/80                      .                .                60.49371         .                .                .
   06/01/80                      .                .                51.5337          .                .                .
   06/15/80                      .                36.31613         .                .                0.248163         0.01320915
   06/23/80                      .                .                33.11078         .                .                .
   06/28/80                      .                60.10392         .                .                0.1373311        0.01483731
   07/27/80                      .                .                44.85020         .                .                .

SITE MEAN                        .                50.8142          76.98576         .                0.2018036        0.01598058
SITE COEFFICIENT OF VARIATION    .                0.3892808        0.6368441        .                0.3434632        0.3956514

NUMBER OF EVENTS FOR THIS STATION      15



                                          FASTTRACK LOAD DATA                  16:18 MONDAY, JANUARY 4, 1982   67

   FAST-TRACK DATA                PROJECT   IL1        SITEID    BASIN4

   EVENT                         PRECIPITATION    COD              TSS              PHOSPHORUS       LEAD             COPPER
   START                         (INCHES)         MILLIGRAMS       MILLIGRAMS       MILLIGRAMS       MILLIGRAMS       MILLIGRAMS
   TIME                                           PER LITER        PER LITER        PER LITER        PER LITER        PER LITER



   03/16/80                      0.56             38               167              0.18             0.065            0.008
   04/03/80                      0.13             50               124              0.29             0.11             0.01
   06/15/80                      0.1              .                119              .                .                .
   06/23/80                      0.9              72               .                0.512            0.17             0.02
   06/28/80                      0.26             71               .                0.503            0.13             0.02

SITE MEAN                        0.4326794        57.82062         137.3495         0.3858945        0.1217139        0.0149611
SITE COEFFICIENT OF VARIATION    1.182239         0.3661887        0.1865042        0.5332417        0.4224929        0.5012649

NUMBER OF EVENTS FOR THIS STATION      5
```

```
                                        LFILE(STORET) LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   19

LFILE (STORET) DATA
                               PROJECT   22ILCITY                  SITEID        BASINS

EVENT                          BOD            COD            TSS            PHOSPHORUS     LEAD           COPPER
START                          MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
TIME                                          PER LITER      PER LITER      PER LITER      PER LITER      PER LITER
                               310            340            530            665            1051           1042



03/16/80                       .              58.4325        78.12543       0.2590686      0.1934925      0.0192807
03/16/80                       .              58.4325        78.12543       0.2590686      0.1934925      0.0192807
03/28/80                       .              .              146.1149       .              .              .
03/28/80                       .              .              146.1149       .              .              .
03/30/80                       .              .              85.00847       .              .              .
03/30/80                       .              .              85.00847       .              .              .
04/03/80                       .              42.14572       200.7396       0.4022798      0.1801088      0.02805741
04/03/80                       .              42.14572       200.7396       0.4022798      0.1801088      0.02805741
04/08/80                       .              .              115.7088       .              .              .
04/08/80                       .              .              115.7088       .              .              .
05/12/80                       .              319.6733       131.8773       1.625831       0.5007062      0.06555597
05/12/80                       .              319.6733       131.8773       1.625831       0.5007062      0.06555597
05/12/80                       .              182.9302       70.2848        0.8018149      0.4140929      0.05617132
05/12/80                       .              182.9302       70.2848        0.8018149      0.4140929      0.05617132
05/16/80                       .              .              258.9289       .              .              .
05/16/80                       .              .              258.9289       .              .              .
05/17/80                       .              114.0142       86.84897       0.5741569      0.2830306      0.04143267
05/17/80                       .              114.0142       86.84897       0.5741569      0.2830306      0.04143267
05/30/80                       .              201.3527       165.5803       1.553723       0.2605287      0.04702009
05/30/80                       .              201.3527       165.5803       1.553723       0.2605287      0.04702009
06/01/80                       .              .              116.4815       .              .              .
06/01/80                       .              .              116.4815       .              .              .
06/15/80                       .              .              117.4072       .              .              .
06/15/80                       .              .              117.4072       .              .              .
06/15/80                       .              .              101.5233       .              .              .
06/15/80                       .              .              101.5233       .              .              .
06/23/80                       .              72.92587       .              0.5421657      0.1469285      0.05955513
06/23/80                       .              72.92587       .              0.5421657      0.1469285      0.05955513
06/28/80                       .              139.5901       .              1.195113       0.1703512      0.09888359
06/28/80                       .              139.5901       .              1.195113       0.1703512      0.09888359
07/26/80                       .              .              219.7696       .              .              .
07/27/80                       .              .              82.6695        .              .              .

SITE MEAN                      .              144.8683       130.3101       0.8909148      0.2690612      0.05281844
SITE COEFFICIENT OF VARIATION  .              0.7412707      0.3977742      0.7066708      0.4449391      0.5252925

NUMBER OF EVENTS FOR THIS STATION       32
```

```
                                        FASTTRACK LOAD DATA                        16:18 MONDAY, JANUARY 4, 1982   68

FAST-TRACK DATA                 PROJECT   IL2        SITEID     #15020880033802

EVENT                           PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
START                           (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
TIME                                           PER LITER      PER LITER      PER LITER      PER LITER      PER LITER



04/03/80                        0.25           170            342            0.448          0.598          0.052
05/17/80                        0.37           .              171            0.427          2.43           0.052
05/28/80                        0.93           280            861            0.759          0.768          0.108
07/09/80                        0.23           190            .              0.387          0.261          0.049
07/20/80                        1.33           60             113            0.228          0.16           0.031
08/04/80                        0.39           66             92             0.29           .              0.028
08/19/80                        0.68           53             83             0.228          0.107          0.026
09/22/80                        0.52           .              328            .              .              .

SITE MEAN                       0.599663       143.6388       292.7705       0.3983965      0.7994395      0.04984587
SITE COEFFICIENT OF VARIATION   0.6819863      0.7942832      1.038333       0.4481318      1.655541       0.5283887

NUMBER OF EVENTS FOR THIS STATION       8
```

```
                                          FASTTRACK LOAD DATA                       16:18 MONDAY, JANUARY 4, 1982   69

    FAST-TRACK DATA                  PROJECT   MA1      SITEID    P1

    EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
    START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
    TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER



    06/29/80                         2.14           150           32            0.2           0.117         0.071
    07/08/80                         0.41           48            57            0.23          0.217         0.061
    07/17/80                         0.38           85            122           1.58          0.29          0.079
    07/29/80                         1.81           62            8             0.56          0.12          0.05
    08/02/80                         0.1            68            26            0.15          0.15          0.056
    08/03/80                         0.13           26            42            0.52          0.13          0.079
    09/10/80                         0.12           100           39            0.15          0.13          0.1
    09/18/80                         0.76           96            324           0.48          0.2           0.09

SITE MEAN                            0.8344331      81.20623      85.69748      0.4896491     0.1699085     0.07353801
SITE COEFFICIENT OF VARIATION        1.804796       0.5736233     1.516243      0.9746267     0.3403469     0.2419718

NUMBER OF EVENTS FOR THIS STATION      8


                                          FASTTRACK LOAD DATA                       16:18 MONDAY, JANUARY 4, 1982   70

    FAST-TRACK DATA                  PROJECT   MA1      SITEID    P2

    EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
    START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
    TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER



    07/17/80                         0.38           101           600           1.28          0.33          0.11
    07/29/80                         1.81           .             118           .             0.4           0.12
    08/02/80                         0.1            78            80            0.57          0.07          0.04
    08/03/80                         0.13           33            231           0.5           0.35          0.11
    08/11/80                         0.11           67            18            0.26          0.15          0.08
    09/10/80                         0.12           178           110           1.68          0.69          0.13
    09/18/80                         0.76           154           790           1.59          0.77          0.17
    11/28/80                         1.54           .             .             .             .             .
    12/03/80                         0.16           .             .             .             .             .

SITE MEAN                            0.6032994      106.6845      351.4636      1.056937      0.4391921     0.1117818
SITE COEFFICIENT OF VARIATION        1.715011       0.6754323     2.052042      0.8748956     1.02224       0.4899871

NUMBER OF EVENTS FOR THIS STATION      9


                                          FASTTRACK LOAD DATA                       16:18 MONDAY, JANUARY 4, 1982   71

    FAST-TRACK DATA                  PROJECT   MA1      SITEID    P3

    EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
    START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
    TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER



    07/17/80                         0.38           95            735           1.6           0.35          0.1
    08/02/80                         0.1            64            69            0.48          0.19          0.11
    08/11/80                         0.11           66            87            0.38          0.16          0.085
    09/10/80                         0.12           109           78            1.1           0.13          0.1
    09/18/80                         0.76           204           481           2.3           0.63          0.16
    09/26/80                         0.31           81            53            1.1           0.15          0.086
    11/28/80                         1.54           .             .             .             .             .

SITE MEAN                            0.5084091      103.8298      257.0775      1.227995      0.2714789     0.1071279
SITE COEFFICIENT OF VARIATION        1.423653       0.4486623     1.746811      0.7850122     0.6724729     0.2349082

NUMBER OF EVENTS FOR THIS STATION      7
```

```
                                           FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   72

   FAST-TRACK DATA                  PROJECT   MA1       SITEID    P4

   EVENT                            PRECIPITATION  COD             TSS             PHOSPHORUS      LEAD            COPPER
   START                            (INCHES)       MILLIGRAMS      MILLIGRAMS      MILLIGRAMS      MILLIGRAMS      MILLIGRAMS
   TIME                                            PER LITER       PER LITER       PER LITER       PER LITER       PER LITER


   06/16/80                         0.2            162             168             0.56            .               .
   06/29/80                         2.14           92              47              0.66            0.3             0.08
   07/17/80                         0.38           104             320             1.61            0.42            0.17
   08/02/80                         0.1            47              58              0.2             0.094           0.064
   08/03/80                         0.13           .               106             .               .               .
   08/11/80                         0.11           45              12              0.1             0.024           0.024
   09/10/80                         0.12           62              14              0.31            0.115           0.048
   09/18/80                         0.76           104             500             0.8             0               0.04

SITE MEAN                           0.4793688      89.50699        195.1639        0.671149        0.2381249       0.07386099
SITE COEFFICIENT OF VARIATION       1.544699       0.4989723       2.310274        1.174516        1.590778        0.7679381

NUMBER OF EVENTS FOR THIS STATION      8


                                           FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   73

   FAST-TRACK DATA                  PROJECT   MA1       SITEID    P5

   EVENT                            PRECIPITATION  COD             TSS             PHOSPHORUS      LEAD            COPPER
   START                            (INCHES)       MILLIGRAMS      MILLIGRAMS      MILLIGRAMS      MILLIGRAMS      MILLIGRAMS
   TIME                                            PER LITER       PER LITER       PER LITER       PER LITER       PER LITER


   06/20/80                         0.28           46              19              0.07            .               .
   06/29/80                         2.14           148             21              0.13            0.24            0.15
   07/08/80                         0.41           59              79              0.25            0.24            0.06
   07/17/80                         0.38           48              122             1.41            0.38            0.15
   07/29/80                         1.81           77              42              0.56            0.23            0.13
   08/02/80                         0.1            115             17              0.03            0.06            0.1
   08/03/80                         0.13           25              56              0.024           0.072           0.058
   08/11/80                         0.11           45              4               0.026           0.057           0.075

SITE MEAN                           0.7096209      71.74562        53.17262        0.368114        0.1968674       0.1048203
SITE COEFFICIENT OF VARIATION       1.788182       0.6186321       1.480761        3.001112        0.9382051       0.4322257

NUMBER OF EVENTS FOR THIS STATION      8


                                           FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   74

   FAST-TRACK DATA                  PROJECT   MA1       SITEID    P6

   EVENT                            PRECIPITATION  COD             TSS             PHOSPHORUS      LEAD            COPPER
   START                            (INCHES)       MILLIGRAMS      MILLIGRAMS      MILLIGRAMS      MILLIGRAMS      MILLIGRAMS
   TIME                                            PER LITER       PER LITER       PER LITER       PER LITER       PER LITER


   09/10/80                         0.12           118             33              0.78            0.33            0.08
   09/18/80                         0.76           99              249             0.75            0.39            0.05
   11/28/80                         1.54           22              6               0.052           .               .
   12/03/80                         0.16           15              3               0.036           .               0.017
   12/10/80                         0.04           15              1               0.024           .               0.004

SITE MEAN                           0.7237472      60.37362        112.5820        0.5172395       0.3612597       0.05531311
SITE COEFFICIENT OF VARIATION       2.768308       1.364981        10.36292        4.144468        0.1185383       2.205985

NUMBER OF EVENTS FOR THIS STATION      5
```

```
                                                   FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   75

    FAST-TRACK DATA                  PROJECT   MI3       SITEID    PITAARETBNNINLT

    EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
    START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
    TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


    06/30/79                         2.25           .             136           0.26          0.11          0.01
    10/22/79                         0.25           .             70            0.5           0.07          0.02
    08/10/80                         0.4            42            48            0.16          0.041         .
    08/10/80                         0.4            42            47            0.16          0.04          .
    09/09/80                         0.9            .             65            0.19          .             .
    09/09/80                         0.9            .             65            0.19          0.08          .
    09/17/80                         0.67           33            48            0.16          0.033         .
    09/17/80                         0.67           33            48            0.16          0.02          .
    10/24/80                         0.45           51            41            0.33          0.047         .
    10/24/80                         0.45           51            41            0.33          0.05          .
    02/17/81                         .              42            40            0.23          .             .

SITE MEAN                            0.7297964      42.10252      62.72326      0.2420575     0.05054435    0.01598706
SITE COEFFICIENT OF VARIATION        0.6727471      0.1795844     0.3955487     0.3985752     0.5018807     0.521092

NUMBER OF EVENTS FOR THIS STATION       11


                                                   FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   76

    FAST-TRACK DATA                  PROJECT   MI3       SITEID    PITAARETBNSINLT

    EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
    START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
    TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


    06/30/79                         2.25           .             52            0.13          0.01          0.005
    10/22/79                         0.25           .             22            0.04          0.003         0.001
    08/10/80                         0.4            28            40            0.07          0.001         .
    08/10/80                         0.4            28            40            0.07          0.01          .
    09/09/80                         0.9            32            47            0.13          0.009         .
    09/09/80                         0.9            32            47            0.13          0.09          .
    09/17/80                         0.67           27            41            0.12          0.006         .
    09/17/80                         0.67           27            41            0.12          0.005         .
    10/24/80                         0.45           26            68            0.11          0.011         .
    10/24/80                         0.45           26            68            0.12          0.01          .
    02/17/81                         .              51            102           0.32          .             .

SITE MEAN                            0.7297964      30.77205      51.98768      0.1287865     0.01888687    0.004272911
SITE COEFFICIENT OF VARIATION        0.6727471      0.2153033     0.4089802     0.5541898     1.634308      1.62835

NUMBER OF EVENTS FOR THIS STATION       11


                                                   FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   77

    FAST-TRACK DATA                  PROJECT   MI3       SITEID    SR WETLANDS INT

    EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
    START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
    TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


    08/20/80                         1.75           37            69            0.17          0.012         .
    08/20/80                         1.75           .             69            0.17          0.02          .
    02/17/81                         .              42            84            .             .             .
    04/11/81                         1.1            28            82            0.14          0.01          .
    04/13/81                         0.89           26            139           0.18          0.012         .
    04/22/81                         0.95           33            55            0.1           0.006         .
    05/29/81                         0.59           26            17            0.05          .             .

SITE MEAN                            1.191277       32.09648      78.65708      0.1401844     0.01224952    .
SITE COEFFICIENT OF VARIATION        0.4800687      0.2011566     0.7239527     0.5266365     0.4534759     .

NUMBER OF EVENTS FOR THIS STATION       7
```

```
                                              FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   78

    FAST-TRACK DATA                    PROJECT   MI3       SITEID    TRAV CK RT BN I

    EVENT                              PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
    START                              (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
    TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


    04/11/81                           1.1            26             34             0.08           0.001          .
    04/13/81                           1              18             42             0.12           0.001          .
    04/22/81                           0.95           23             39             0.09           0.002          .
    05/09/81                           1.4            28             9              0.06           0.001          .
    06/13/81                           1.5            29             22             0.1            0.002          .

SITE MEAN                              1.194723       24.91058       31.35879       0.09068241     0.001418119    .
SITE COEFFICIENT OF VARIATION          0.2057117      0.198692       0.7062419      0.2636188      0.3937524      .

NUMBER OF EVENTS FOR THIS STATION      5
```

```
                                              FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   79

    FAST-TRACK DATA                    PROJECT   MI1       SITEID    F02

    EVENT                              PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
    START                              (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
    TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


    05/30/80                           0.28           92             170            0.75           0.25           0.071
    06/01/80                           0.43           64             32             0.24           0.027          0.024
    06/05/80                           0.5            64             76             0.31           0.11           .
    07/05/80                           0.92           92             240            1.1            .              .
    07/16/80                           0.96           70             93             0.67           .              .
    08/02/80                           0.39           66             36             0.23           .              .
    08/10/80                           0.53           55             82             0.56           .              .
    10/24/80                           0.43           .              31             0.42           .              .

SITE MEAN                              0.5594517      72.02281       98.53828       0.5471023      0.1705958      0.05539405
SITE COEFFICIENT OF VARIATION          0.4401557      0.196103       0.8947486      0.6149997      1.596639       0.8948496

NUMBER OF EVENTS FOR THIS STATION      8
```

```
                                              FASTTRACK LOAD DATA                     16:18 MONDAY, JANUARY 4, 1982   80

    FAST-TRACK DATA                    PROJECT   MI1       SITEID    F04

    EVENT                              PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
    START                              (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
    TIME                                              PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


    04/03/80                           0.63           77             130            0.19           0.24           0.016
    04/28/80                           0.28           81             36             0.14           0.056          0.015
    05/30/80                           0.28           150            220            0.47           0.41           0.03
    06/01/80                           0.43           46             19             0.1            0.02           0.008
    06/05/80                           0.63           89             54             0.1            0.13           0.012
    07/05/80                           0.92           49             100            0.27           .              0.016
    07/16/80                           0.96           47             97             0.01           .              .
    08/02/80                           0.39           63             29             0.12           .              .
    08/10/80                           0.53           49             60             0.15           .              .
    09/09/80                           0.22           .              70             0.26           .              .
    09/22/80                           0.49           .              6              0.12           .              .
    10/14/80                           0.44           .              74             0.2            .              .
    10/16/80                           0.31           6              9              0.08           .              .
    10/17/80                           0.43           53             32             0.11           0.063          0.058
    10/24/80                           0.43           49             11             0.25           0.036          0.008

SITE MEAN                              0.4933909      70.38539       70.77238       0.1948978      0.1504599      0.01997653
SITE COEFFICIENT OF VARIATION          0.4396616      0.8973375      1.389911       1.051641       1.456445       0.7196353

NUMBER OF EVENTS FOR THIS STATION      15
```

21

```
                                             FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   81

  FAST-TRACK DATA                   PROJECT   MI1       SITEID    ROP

  EVENT                             PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
  START                             (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
  TIME                                             PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


  04/03/80                          0.63           56            330           0.14          0.9           0.021
  06/01/80                          0.43           42            110           0.39          0.022         0.015
  07/16/80                          0.96           40            230           0.22          .             .
  08/02/80                          0.39           47            43            0.14          .             .
  08/10/80                          0.53           44            210           0.37          .             .
  09/22/80                          0.49           75            68            0.41          .             .
  10/14/80                          0.44           .             150           0.37          .             .
  10/17/80                          0.43           60            130           0.33          0.61          0.013
  10/24/80                          0.43           67            60            0.17          .             .

SITE MEAN                           0.5254051      54.03805      153.5539      0.2874878     1.037118      0.01649104
SITE COEFFICIENT OF VARIATION       0.2857929      0.2348596     0.7639085     0.4789952     7.944341      0.2499765

NUMBER OF EVENTS FOR THIS STATION       9
```

```
                                             FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   82

  FAST-TRACK DATA                   PROJECT   MI1       SITEID    R10

  EVENT                             PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
  START                             (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
  TIME                                             PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


  05/30/80                          0.28           120           320           0.55          0.29          0.044
  06/05/80                          0.63           57            170           0.26          .             0.016
  08/02/80                          0.39           54            49            0.14          .             .
  08/10/80                          0.53           9             300           0.44          .             .
  09/09/80                          0.22           .             160           0.32          .             .
  09/16/80                          1.63           42            230           0.26          .             .
  10/14/80                          0.44           .             120           0.32          .             .
  10/17/80                          0.43           35            120           0.21          0.046         0.011
  10/24/80                          0.43           .             46            .             .             .

SITE MEAN                           0.5479701      59.41475      178.0969      0.3167189     0.2695632     0.02558541
SITE COEFFICIENT OF VARIATION       0.6121478      1.039363      0.7995779     0.4443151     2.108811      0.8199972

NUMBER OF EVENTS FOR THIS STATION       9
```

```
                                             FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   83

  FAST-TRACK DATA                   PROJECT   NH1       SITEID    1-PKG/PARKINLOT

  EVENT                             PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
  START                             (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
  TIME                                             PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


  07/17/80                          0.38           80            170           0.099         0.42          0.1
  07/29/80                          0.58           .             16            0.1           0.12          0.1
  08/05/80                          0.31           57            59            0.048         0.18          0.1
  08/15/80                          0.02           108           30            0.309         0.31          0.1
  08/20/80                          0.34           98            24            0.15          0.31          0.1
  09/02/80                          0.28           149           148           0.34          0.01          0.1
  09/10/80                          0.06           353           54            0.33          0.6           0.2
  09/14/80                          0.18           155           27            .             0.31          0.01
  09/18/80                          0.55           181           95            0.24          0.01          0.02
  09/25/80                          1.03           37            20            0.112         0.1           .
  10/03/80                          1.09           61            38            0.098         0.14          0.03
  10/18/80                          0.42           237           109           .             0.88          0.1
  10/25/80                          2.67           100           47            0.185         0.11          0.1
  04/23/81                          0.73           39            65            0.04          0.15          0.1
  04/29/81                          0.16           169           190           0.273         0.3           0.2
  04/29/81                          0.27           102           115           0.165         0.22          0.1
  05/29/81                          0.22           330           222           0.172         0.365         0.1
  05/31/81                          0.39           72            82            0.158         0.19          0.1
  06/03/81                          0.2            135           139           0.037         0.15          0.1
  06/06/81                          0.08           188           .             0.348         0.365         0.1
  06/09/81                          0.68           86            122           0.175         0.325         0.1

SITE MEAN                           0.5598524      138.6952      93.14539      0.1864151     0.3150759     0.1060585
SITE COEFFICIENT OF VARIATION       1.471073       0.6966006     0.946141      0.793698      1.482526      0.8111976

NUMBER OF EVENTS FOR THIS STATION       21
```

22

```
                                                FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   89
   FAST-TRACK DATA                     PROJECT   SD1        SITEID    06816300

   EVENT                               PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
   START                               (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
   TIME                                               PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


   06/14/80                            .              341            10700          6.42           2              .
   07/12/80                            .              303            6120           2.86           0.46           .
   07/20/80                            .              127            1760           1.16           0.21           .
   07/25/80                            .              127            645            0.89           0.23           .
   08/20/80                            .              165            3700           1.93           0.28           .
   10/15/80                            .              92             1120           0.72           0.13           .

SITE MEAN                              .              196.4154       4578.023       2.434644       0.5415241      .
SITE COEFFICIENT OF VARIATION          .              0.5605369      1.850542       1.196099       1.224          .

NUMBER OF EVENTS FOR THIS STATION      6
```

```
                                                FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   90
   FAST-TRACK DATA                     PROJECT   TX1        SITEID    HART LANE

   EVENT                               PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
   START                               (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
   TIME                                               PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


   02/04/81                            0.28           16             42             .              .
   02/10/81                            0.33           137            201            0.24           .              .
   03/03/81                            .              .              .              .              .              .
   03/07/81                            0.35           34             43             0.192          .              .
   03/07/81                            0.33           34             43             0.19           .              .
   03/12/81                            0.34           53             17             0.112          .              .
   03/12/81                            0.34           .              .              .              .              .
   03/29/81                            0.2            96             316            0.882          .              .
   04/17/81                            0.47           210            334            0.995          .              .
   05/02/81                            0.8            29             21             0.253          .              .
   05/16/81                            0.98           63             153            0.31           .              .
   05/23/81                            .              82             272            0.445          .              .
   05/23/81                            .              .              .              .              .              .
   06/01/81                            0.04           34             84             0.145          .              .
   06/02/81                            0.25           97             183            0.327          .              .
   06/03/81                            0.36           48             34             0.168          .              .
   08/30/81                            0.19           .              9              0.09           .              .
   09/14/81                            .              .              228            0.35           .              .
   09/15/81                            .              .              42             0.25           .              .
SITE MEAN                              0.3674517      73.16728       145.5865       0.3283534      .
SITE COEFFICIENT OF VARIATION          0.7777799      0.8116161      1.650292       0.7552314      .              .

NUMBER OF EVENTS FOR THIS STATION      19
```

```
                                                FASTTRACK LOAD DATA                          16:18 MONDAY, JANUARY 4, 1982   91
   FAST-TRACK DATA                     PROJECT   TX1        SITEID    COLLINGWOOD

   EVENT                               PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
   START                               (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
   TIME                                               PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


   04/17/81                            0.49           102            .              .              .              .
   05/16/81                            1.25           83             .              .              .              .
   05/23/81                            1.1            133            .              .              .              .
   06/01/81                            0.19           59             197            0.267          .              .
   06/02/81                            0.46           36             371            0.168          .              .
   06/05/81                            0.35           39             37             0.144          .              .
   06/25/81                            1.85           104            165            0.285          .              .
   07/05/81                            1.95           57             180            0.34           .              .
   08/07/81                            0.45           145            131            0.168          .              .

SITE MEAN                              0.8995625      85.99982       198.0092       0.2239391      .
SITE COEFFICIENT OF VARIATION          0.9041327      0.5439013      0.8892807      0.3426537      .              .

NUMBER OF EVENTS FOR THIS STATION      9
```

```
                                                FASTTRACK LOAD DATA                      16:18 MONDAY, JANUARY 4, 1982   92

FAST-TRACK DATA                  PROJECT   WA1        SITEID    20DBELL0586

EVENT                            PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
START                            (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
TIME                                            PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


04/14/80                         0.15           67             87             0.27           0.53           .
04/18/80                         1.33           13             81             0.187          0.1            .
05/21/80                         0.19           48             119            0.368          0.38           .
05/24/80                         0.69           16             88             0.15           0.15           .
05/27/80                         0.09           31             92             0.116          0.12           .
06/01/80                         0.19           78             222            0.423          0.86           .
06/05/80                         0.18           26             59             0.1            0.12           .
06/16/80                         0.2            110            259            0.56           1.02           .
06/24/80                         0.72           41             95             0.275          0.19           .
06/25/80                         0.08           57             114            0.258          0.38           .
07/11/80                         0.28           49             85             0.257          0.23           .
07/14/80                         0.14           43             137            0.172          0.2            .
08/26/80                         0.04           85             84             0.57           0.39           .
08/27/80                         0.43           75             190            3.61           0.53           .
09/01/80                         0.57           30             54             0.078          0.1            .
09/06/80                         0.23           47             60             0.271          0.26           .
09/12/80                         0.12           32             24             0.149          0.1            .
09/13/80                         0.16           39             156            0.1            0.1            .
09/20/80                         0.25           80             199            0.383          0.385          .
09/29/80                         0.19           30             2680           0.306          0.78           .
09/29/80                         0.09           22             102            0.39           0.29           .
10/08/80                         0.11           78             168            0.256          0.28           .
10/12/80                         0.16           22             27             0.202          0.1            .
10/24/80                         0.17           80             138            0.375          0.29           .
10/31/80                         0.74           41             106            0.212          0.18           .
11/01/80                         0.36           63             188            0.383          0.31           .
11/03/80                         0.51           35             85             0.155          0.1            .
11/08/80                         0.41           36             68             0.135          0.1            .
11/14/80                         0.15           83             125            0.17           0.15           .
11/19/80                         0.19           38             442            0.92           0.25           .
11/20/80                         1.55           32             92             0.293          0.1            .
11/23/80                         0.22           22             72             0.52           0.15           .
11/27/80                         0.7            28             83             0.151          0.1            .
11/28/80                         0.83           23             66             0.126          0.1            .
12/02/80                         0.69           34             78             0.201          0.1            .
12/03/80                         0.32           28             66             0.099          0.2            .
12/04/80                         0.04           27             62             0.123          0.1            .
12/14/80                         0.17           77             152            0.307          0.3            .
12/20/80                         0.28           36             109            0.236          0.2            .
12/21/80                         0.04           33             113            0.211          0.1            .
12/24/80                         0.26           45             120            0.221          0.2            .
12/24/80                         0.47           55             93             0.141          0.1            .
12/26/80                         0.32           23             68             0.124          0.1            .
12/29/80                         0.72           22             60             0.103          0.1            .
01/17/81                         0.15           45             142            0.51           0.2            .
01/23/81                         0.48           57             161            0.283          0.3            .
01/26/81                         0.16           24             81             0.272          0.1            .
01/28/81                         0.6            13             69             0.087          0.1            .
```

```
                                                FASTTRACK LOAD DATA                      16:18 MONDAY, JANUARY 4, 1982   93

FAST-TRACK DATA                  PROJECT   WA1        SITEID    20DBELL0586

EVENT                            PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
START                            (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
TIME                                            PER LITER      PER LITER      PER LITER      PER LITER      PER LITER


02/11/81                         1              43             90             0.218          0.137          .
02/13/81                         0.24           27             66             0.134          0.1            .
02/13/81                         0.22           71             140            0.371          0.3            .
02/14/81                         0.78           68             242            0.469          0.3            .
02/17/81                         0.16           31             74             0.146          0.15           .
02/18/81                         0.55           58             2825           0.359          0.3            .
02/19/81                         0.03           19             105            0.136          0.1            .
03/24/81                         0.21           32             71             0.163          0.1            .
03/29/81                         0.14           39             66             0.115          0.1            .
04/05/81                         0.18           42             87             0.275          0.1            .
04/06/81                         0.34           42             135            0.488          0.2            .
04/07/81                         0.28           27             42             0.185          0.1            .
04/10/81                         0.36           32             117            0.226          0.1            .
04/12/81                         0.12           29             157            0.51           0.1            .
04/20/81                         0.19           50             78             0.21           0.2            .
04/22/81                         0.25           36             76             0.16           0.1            .
04/23/81                         0.07           38             43             0.117          0.1            .
04/27/81                         0.53           35             88             0.254          0.2            .
05/07/81                         0.23           43             121            0.261          0.2            .
05/11/81                         0.36           67             239            0.258          0.1            .
05/14/81                         0.18           62             161            0.221          0.3            .
05/18/81                         0.08           70             198            0.366          0.3            .
SITE MEAN                        0.345381       44.1662        145.1991       0.2808522      0.2004486      .
SITE COEFFICIENT OF VARIATION    1.008674       0.4964426      0.8729391      0.6880963      0.6503183      .

NUMBER OF EVENTS FOR THIS STATION     70
```

```
                                                  FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   94

FAST-TRACK DATA                 PROJECT   WA1        SITEID    20MBELL0588

EVENT                         PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
START                         (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
TIME                                         PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


03/12/80                      .              23            70            0.13          0.1           .
03/26/80                      .              79            230           0.33          0.35          .
04/05/80                      0.43           50            112           0.25          0.27          .
04/08/80                      0.57           38            188           0.26          0.2           .
04/09/80                      0.2            40            90            0.19          0.2           .
04/14/80                      0.18           54            196           0.59          0.33          .
04/18/80                      1.19           15            43            0.097         0.1           .
07/11/80                      0.22           69            182           0.29          0.21          .
07/14/80                      0.15           37            127           0.145         0.1           .
08/26/80                      0.08           128           106           0.95          0.51          .
08/27/80                      0.18           102           266           1.17          0.49          .
08/28/80                      0.37           35            144           0.091         0.2           .
09/01/80                      0.5            29            58            0.123         0.1           .
09/06/80                      0.27           87            90            0.305         0.22          .
09/12/80                      0.08           28            72            0.11          0.1           .
09/13/80                      0.14           43            90            0.117         0.1           .
09/19/80                      0.09           56            82            0.207         0.1           .
09/20/80                      0.38           76            168           0.357         0.28          .
09/29/80                      0.43           42            115           0.177         0.136         .
10/08/80                      0.19           39            178           0.36          0.25          .
10/24/80                      0.16           102           140           0.246         0.15          .
10/31/80                      0.78           51            57            0.149         0.09          .
11/01/80                      0.29           46            100           0.18          0.18          .
11/03/80                      0.6            32            95            0.155         0.06          .
11/06/80                      1.18           51            93            0.081         0.1           .
11/08/80                      0.43           35            68            0.182         0.1           .
11/14/80                      0.12           50            250           0.227         0.2           .
11/19/80                      0.21           41            73            0.165         0.1           .
11/20/80                      1.66           30            60            0.15          0.1           .
11/25/80                      0.15           31            29            0.263         0.1           .
11/27/80                      0.71           29            49            0.112         0.1           .
11/28/80                      0.86           34            53            0.103         0.1           .
12/02/80                      0.97           42            68            0.17          0.1           .
12/03/80                      0.46           26            71            0.083         0.1           .
12/14/80                      0.11           69            100           0.239         0.2           .
12/20/80                      0.43           58            95            0.178         0.1           .
12/24/80                      0.26           62            98            0.161         0.1           .
12/24/80                      0.51           20            60            0.089         0.2           .
12/25/80                      1.28           27            76            0.134         0.1           .
12/26/80                      0.34           20            83            0.21          0.1           .
12/29/80                      1.14           19            91            0.092         0.1           .
01/17/81                      0.22           47            125           0.37          0.2           .
01/28/81                      0.63           20            68            0.085         0.1           .
02/11/81                      0.91           52            80            0.163         0.1           .
02/13/81                      0.2            30            62            0.213         0.1           .
02/13/81                      0.3            64            108           0.227         0.2           .
02/17/81                      0.16           43            90            0.07          0.1           .
02/18/81                      0.71           30            159           0.258         0.2           .
```

```
                                                  FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   95

FAST-TRACK DATA                 PROJECT   WA1        SITEID    20MBELL0588

EVENT                         PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
START                         (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
TIME                                         PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


02/19/81                      0.02           12            118           0.048         0.1           .
03/24/81                      0.26           72            76            0.22          0.1           .
03/28/81                      0.18           33            62            0.122         0.1           .
04/02/81                      0.16           108           191           0.505         0.2           .
04/05/81                      0.16           45            58            0.172         0.1           .
04/06/81                      0.38           45            147           0.545         0.2           .
04/07/81                      0.22           21            89            0.068         0.1           .
04/10/81                      0.3            27            67            0.2           0.1           .
04/12/81                      0.13           46            117           0.255         0.2           .
04/22/81                      0.08           46            128           0.145         0.1           .
04/27/81                      0.47           33            72            0.186         0.2           .
05/03/81                      0.21           95            108           0.291         0.1           .
05/07/81                      0.16           82            136           0.308         0.2           .
05/07/81                      0.33           61            188           0.357         0.2           .
05/10/81                      0.29           48            87            0.202         0.1           .

SITE MEAN                     0.4156447      46.87828      104.9911      0.2398883     0.1544186     .
SITE COEFFICIENT OF VARIATION 1.001046       0.5212644     0.473148      0.8798273     0.4812612     .

NUMBER OF EVENTS FOR THIS STATION      63
```

```
                                   FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   96

FAST-TRACK DATA                  PROJECT   MI1      SITEID   413630

EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


05/28/80                         0.86           9             198           0.31          0.4           .
09/09/80                         1.24           160           72            0.1           0.15          .
09/22/80                         0.58           73            82            0.14          0.15          .
09/22/80                         0.24           46            92            0.16          0.2           .
05/23/81                         0.05           150           479           0.72          0.95          .
05/29/81                         0.27           150           272           0.38          0.46          .
06/08/81                         0.27           130           144           0.64          0.6           .
06/13/81                         0.58           130           51            0.16          0.1           .
06/20/81                         0.18           92            157           0.97          0.5           .
08/26/81                         .              120           202           0.29          0.4           .
08/29/81                         .              120           70            0.14          0.2           .

SITE MEAN                        0.5360208      119.1636      166.8058      0.3728327     0.3857913     .
SITE COEFFICIENT OF VARIATION    1.23517        0.4044021     0.7623551     0.8937225     0.7966797     .

NUMBER OF EVENTS FOR THIS STATION      11
```

```
                                   FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   97

FAST-TRACK DATA                  PROJECT   MI1      SITEID   413631

EVENT                            PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
START                            (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
TIME                                            PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


03/15/80                         .              81            98            0.28          0.3           .
04/03/80                         .              81            132           0.28          0.6           .
04/04/80                         .              150           44            0.12          0.2           .
04/06/80                         .              71            210           0.3           0.6           .
04/09/80                         .              140           38            0.09          0.16          .
05/13/80                         .              45            472           0.8           2             .
05/18/80                         0.21           250           90            0.15          0.35          .
05/28/80                         0.3            55            532           0.79          2.4           .
06/01/80                         .              230           38            0.16          0.19          .
06/02/80                         .              78            161           0.22          0.49          .
06/05/80                         .              42            270           0.37          0.67          .
06/06/80                         .              78            438           0.37          1.2           .
06/07/80                         .              80            348           0.41          1.5           .
06/19/80                         0.23           76            158           0.26          0.47          .
07/05/80                         0.73           73            438           0.44          0.95          .
07/09/80                         0.72           120           206           0.27          0.46          .
07/15/80                         0.28           92            188           0.29          0.61          .
07/16/80                         0.55           110           181           0.2           0.52          .
07/25/80                         0.18           78            64            0.17          0.22          .
08/02/80                         0.19           110           244           0.39          0.58          .
08/02/80                         0.17           180           72            0.14          0.215         .
08/04/80                         3.24           55            246           0.29          1.6           .
08/07/80                         0.97           76            180           0.2           0.45          .
08/07/80                         0.37           63            58            0.12          0.2           .
08/13/80                         0.05           64            68            0.34          0.3           .
08/16/80                         0.73           130           45            0.16          0.33          .
02/22/81                         0.05           170           112           0.26          0.3           .
04/08/81                         1.08           63            280           0.38          0.51          .
04/13/81                         1.42           63            342           0.43          1             .
04/23/81                         .              63            82            0.18          0.3           .
05/29/81                         0.27           46            186           0.38          0.36          .
06/08/81                         0.3            180           336           0.49          0.9           .
06/13/81                         0.59           180           56            0.15          0.2           .
06/15/81                         0.11           76            21            0.14          0.1           .
06/20/81                         0.16           82            390           0.6           1.2           .
07/12/81                         0.71           82            290           0.51          0.9           .
07/17/81                         0.18           170           143           0.25          0.35          .
07/20/81                         .              170           442           0.34          0.6           .
08/14/81                         .              92            49            0.14          0.2           .
08/15/81                         .              92            283           0.29          0.6           .
08/26/81                         .              83            120           0.18          0.3           .
08/29/81                         .              83            236           0.24          0.6           .
08/31/81                         .              61            61            0.12          0.2           .
09/07/81                         .              27            44            0.1           0.05          .

SITE MEAN                        0.5617392      99.50628      202.0914      0.2913495     0.6064536     .
SITE COEFFICIENT OF VARIATION    1.297878       0.4954272     1.020228      0.5767538     0.9409928     .
```

```
                                        FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   98

   FAST-TRACK DATA               PROJECT   WI1      SITEID    413631

   EVENT                         PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
   START                         (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
   TIME                                         PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


NUMBER OF EVENTS FOR THIS STATION      44



                                        FASTTRACK LOAD DATA                    16:18 MONDAY, JANUARY 4, 1982   99

   FAST-TRACK DATA               PROJECT   WI1      SITEID    413632

   EVENT                         PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
   START                         (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
   TIME                                         PER LITER     PER LITER     PER LITER     PER LITER     PER LITER



   06/02/80                      .              26            42            0.18          0.11          .
   06/06/80                      0.67           55            44            0.24          0.14          .
   06/07/80                      0.6            36            27            0.28          0.025         .
   06/28/80                      0.44           41            21            0.14          0.085         .
   09/12/80                      0.95           18            18            0.19          0.05          .
   09/16/80                      0.85           25            28            0.15          0.1           .
   09/20/80                      0.75           22            27            0.24          0.05          .
   09/25/80                      0.15           27            60            0.22          0.05          .
   05/10/81                      0.67           16            49            0.27          0.05          .
   05/24/81                      0.05           55            96            0.34          0.1           .
   05/29/81                      0.08           55            140           0.48          0.24          .
   06/08/81                      0.13           160           394           0.88          0.5           .
   06/13/81                      0.53           160           28            0.15          0.05          .
   06/15/81                      .              27            72            0.23          0.1           .
   06/20/81                      0.26           32            32            0.13          0.095         .

SITE MEAN                        0.5460049      48.96661      66.3864       0.270388      0.1133655     .
SITE COEFFICIENT OF VARIATION    1.264519       0.7861794     0.9740736     0.5399149     0.8435801     .

NUMBER OF EVENTS FOR THIS STATION      15
```

27

```
                                             FASTTRACK LOAD DATA                    16118 MONDAY, JANUARY 4, 1982  100

   FAST-TRACK DATA                  PROJECT   WI1      SITEID    413633

   EVENT                            PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
   START                            (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
   TIME                                            PER LITER      PER LITER      PER LITER      PER LITER      PER LITER



   06/06/80                         0.73           32             216            0.32           0.33           .
   06/07/80                         0.65           58             106            0.34           0.06           .
   06/28/80                         0.48           52             33             0.17           0.1            .
   07/05/80                         0.94           39             131            0.25           0.09           .
   07/09/80                         .              39             41             0.16           0.08           .
   07/16/80                         .              39             75             0.17           0.06           .
   08/02/80                         0.25           28             144            0.34           0.22           .
   08/04/80                         .              28             144            0.33           0.17           .
   08/07/80                         1.2            56             6              0.16           0.05           .
   08/07/80                         0.07           26             8              0.16           0.05           .
   08/11/80                         0.85           26             57             0.27           0.12           .
   09/16/80                         0.81           26             59             0.2            0.05           .
   09/20/80                         0.67           24             76             0.26           0.125          .
   09/25/80                         0.13           34             79             0.22           0.1            .
   10/03/80                         .              40             60             0.29           0.1            .
   11/24/80                         .              40             2              0.12           0.05           .
   12/06/80                         0.59           38             126            0.74           0.22           .
   12/08/80                         0.27           55             19             0.13           0.05           .
   02/22/81                         0.76           20             53             0.3            0.05           .
   04/04/81                         0.74           20             336            0.44           0.25           .
   04/08/81                         0.74           67             106            0.19           0.05           .
   04/10/81                         1.2            67             118            0.3            0.05           .
   04/13/81                         0.52           67             65             0.16           0.05           .
   04/23/81                         .              17             56             0.16           0.05           .
   05/10/81                         0.59           17             11             0.14           0.05           .
   06/08/81                         0.11           24             61             0.27           0.1            .
   06/08/81                         0.14           56             172            0.58           0.26           .
   06/13/81                         0.5            56             32             0.21           0.1            .
   06/22/81                         .              54             58             0.18           0.12           .
   07/12/81                         .              54             158            0.32           0.25           .
   07/12/81                         .              70             94             0.22           0.1            .
   07/13/81                         .              70             110            0.2            0.05           .
   07/18/81                         .              2              313            0.38           0.22           .
   07/20/81                         0.41           2              86             0.2            0.05           .
   07/25/81                         0.38           33             57             0.17           0.1            .
   08/07/81                         0.31           33             270            0.38           0.3            .
   08/14/81                         .              33             119            0.26           0.2            .
   08/15/81                         .              33             158            0.22           0.1            .
   08/28/81                         .              33             14             0.09           0.05           .
   08/29/81                         .              33             57             0.14           0.1            .
   08/31/81                         .              33             41             0.16           0.05           .
   09/07/81                         .              33             124            0.21           0.05           .

SITE MEAN                           0.6035123      42.37976       114.6907       0.2491974      0.1126706      .
SITE COEFFICIENT OF VARIATION       0.8820422      0.8528413      1.446717       0.4461515      0.6908119      .

NUMBER OF EVENTS FOR THIS STATION       42



                                             FASTTRACK LOAD DATA                    16118 MONDAY, JANUARY 4, 1982  101

   FAST-TRACK DATA                  PROJECT   WI1      SITEID    413634

   EVENT                            PRECIPITATION  COD            TSS            PHOSPHORUS     LEAD           COPPER
   START                            (INCHES)       MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS     MILLIGRAMS
   TIME                                            PER LITER      PER LITER      PER LITER      PER LITER      PER LITER



   06/05/80                         .              36             144            0.14           0.11           .
   06/28/80                         .              39             12             0.17           0.1            .
   09/16/80                         0.55           51             17             0.06           0.12           .
   09/20/80                         0.75           29             14             0.05           0.05           .
   09/22/80                         0.18           23             1              0.67           0.05           .
   09/22/80                         0.77           34             46             0.07           0.1            .
   09/25/80                         0.08           34             22             0.09           0.05           .
   10/03/80                         .              52             12             0.1            0.05           .
   05/10/81                         0.56           65             5              0.05           0.05           .
   05/23/81                         .              65             142            0.52           0.45           .
   05/29/81                         0.12           65             232            0.43           0.51           .
   05/29/81                         0.14           97             122            0.16           0.32           .
   06/08/81                         0.18           120            48             0.18           0.2            .
   06/15/81                         0.1            120            71             0.17           0.2            .
   06/20/81                         0.2            96             20             0.06           0.1            .
   08/26/81                         .              98             12             0.06           0.1            .
   08/27/81                         .              98             13             0.03           0.05           .
   08/29/81                         .              27             10             0.03           0.05           .
   08/31/81                         .              27             100            0.17           0.2            .

SITE MEAN                           0.3412321      62.6342        67.4519        0.1680818      0.149013       .
SITE COEFFICIENT OF VARIATION       1.007453       0.6008044      2.345209       1.113342       0.9148335      .

NUMBER OF EVENTS FOR THIS STATION       19
```

```
                                              FASTTRACK LOAD DATA                 16:18 MONDAY, JANUARY 4, 1982  102

FAST-TRACK DATA                   PROJECT   MI1      SITEID    413635

EVENT                             PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
START                             (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
TIME                                             PER LITER     PER LITER     PER LITER     PER LITER     PER LITER



04/03/80                          0.08           60            14            0.08          0.05          .
04/06/80                          .              18            81            0.12          0.32          .
04/08/80                          0.52           81            278           0.2           0.5           .
04/09/80                          0.57           100           15            0.04          0.1           .
04/14/80                          .              27            53            0.06          0.22          .
04/20/80                          0.23           45            46            0.11          0.6           .
04/28/80                          0.45           65            20            0.06          0.1           .
05/13/80                          0.21           30            240           0.31          0.75          .
05/18/80                          0.13           30            27            0.07          0.1           .
06/01/80                          .              35            53            0.13          0.19          .
06/02/80                          0.25           73            63            0.12          0.22          .
06/05/80                          0.89           69            192           0.16          0.35          .
06/06/80                          0.72           58            129           0.14          0.22          .
06/07/80                          0.53           40            90            0.11          0.22          .
06/19/80                          .              39            58            0.18          0.23          .
07/16/80                          .              140           25            0.09          0.1           .
08/02/80                          0.26           140           162           0.2           0.335         .
08/02/80                          0.24           180           46            0.08          0.14          .
08/04/80                          2.79           140           100           0.14          0.26          .
08/11/80                          0.57           65            27            0.11          0.075         .
08/13/80                          0.05           28            20            0.5           0.19          .
08/19/80                          0.58           28            30            0.05          0.1           .
09/07/80                          0.4            28            9             0.07          0.05          .
09/09/80                          1.26           28            75            0.06          0.175         .
09/12/80                          1.37           28            26            0.08          0.05          .
09/16/80                          0.77           43            25            0.06          0.15          .
09/20/80                          0.72           35            60            0.07          0.13          .
09/25/80                          0.09           38            28            0.06          0.1           .
10/03/80                          .              49            48            0.15          0.2           .
10/16/80                          0.28           49            6             0.05          0.05          .
10/16/80                          0.29           50            17            0.06          0.1           .
10/24/80                          0.2            50            29            0.13          0.15          .
11/14/80                          0.55           76            18            0.06          0.12          .
11/24/80                          .              76            8             0.1           0.12          .
12/02/80                          .              54            72            0.14          0.5           .
12/06/80                          0.64           54            68            0.12          0.4           .
02/16/81                          .              98            108           0.16          0.5           .
02/22/81                          .              114           74            0.1           0.4           .
04/06/81                          1.28           69            564           0.38          0.9           .
04/07/81                          .              160           109           0.14          0.24          .
04/08/81                          0.32           160           199           0.11          0.26          .
04/10/81                          .              160           198           0.14          0.24          .
04/10/81                          .              160           198           0.14          0.24          .
04/13/81                          1.21           160           138           0.06          0.12          .
05/29/81                          0.16           22            168           0.23          0.32          .
05/29/81                          0.22           120           104           0.12          0.25          .
06/20/81                          0.21           110           47            0.07          0.16          .
07/12/81                          1.21           110           148           0.34          0.25          .
```

```
                                              FASTTRACK LOAD DATA                 16:18 MONDAY, JANUARY 4, 1982  103

FAST-TRACK DATA                   PROJECT   MI1      SITEID    413635

EVENT                             PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
START                             (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
TIME                                             PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


07/12/81                          0.64           100           100           0.1           0.15          .
07/13/81                          3.56           100           40            0.05          0.05          .
07/18/81                          .              17            130           0.13          0.2           .
07/20/81                          0.27           17            60            0.1           0.15          .
08/14/81                          .              63            81            0.12          0.2           .
08/15/81                          .              65            137           0.12          0.2           .
08/26/81                          .              65            43            0.06          0.05          .
08/27/81                          .              65            25            0.06          0.1           .
08/29/81                          .              42            42            0.08          0.2           .
08/31/81                          .              42            45            0.08          0.05          .
09/07/81                          .              28            23            0.06          0.05          .
SITE MEAN                         0.658003       71.12706      87.70452      0.1191422     0.2212952     .
SITE COEFFICIENT OF VARIATION     1.182169       0.7010894     1.204657      0.5898431     0.8279833     .

NUMBER OF EVENTS FOR THIS STATION      59
```

```
                                   FASTTRACK LOAD DATA                       16:18 MONDAY, JANUARY 4, 1982  104
   FAST-TRACK DATA                     PROJECT   WI1       SITEID    #13636

   EVENT                           PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
   START                           (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
   TIME                                           PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


   04/04/81                        0.61           30            1152          1.28          1.1           .
   04/07/81                        0.2            240           972           1.02          0.96          .
   04/08/81                        0.86           240           208           0.31          0.18          .
   04/10/81                        .              72            242           0.82          0.32          .
   04/13/81                        1.29           72            162           0.2           0.18          .
   04/23/81                        .              60            100           0.9           0.15          .
   05/10/81                        0.77           60            26            0.6           0.05          .
   05/29/81                        .              78            692           2.9           0.78          .
   05/29/81                        .              490           306           1.2           0.42          .
   06/08/81                        0.13           580           38            0.46          0.1           .
   06/08/81                        0.18           580           602           2.5           0.75          .
   06/13/81                        0.55           580           52            0.4           0.1           .
   06/20/81                        0.19           54            98            0.33          0.2           .
   07/12/81                        .              54            253           0.68          0.5           .
   07/12/81                        .              120           205           0.44          0.35          .
   07/13/81                        2.31           120           118           0.25          0.3           .
   07/18/81                        0.52           53            221           0.44          0.35          .
   07/20/81                        0.3            82            33            0.22          0.15          .
   08/14/81                        .              36            167           0.5           1.7           .
   08/15/81                        .              36            239           0.34          0.3           .
   08/29/81                        .              48            33            0.19          0.1           .
   08/31/81                        .              48            128           0.3           0.2           .
   09/07/81                        .              45            30            0.18          0.05          .

SITE MEAN                          0.6809089      156.2122      280.3156      0.6989971     0.8158159     .
SITE COEFFICIENT OF VARIATION      1.087556       1.246966      1.562927      0.9162922     1.205293      .

NUMBER OF EVENTS FOR THIS STATION       23
```

```
                                   FASTTRACK LOAD DATA                       16:18 MONDAY, JANUARY 4, 1982  105
   FAST-TRACK DATA                     PROJECT   WI1       SITEID    #13637

   EVENT                           PRECIPITATION  COD           TSS           PHOSPHORUS    LEAD          COPPER
   START                           (INCHES)       MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS    MILLIGRAMS
   TIME                                           PER LITER     PER LITER     PER LITER     PER LITER     PER LITER


   06/08/81                        0.11           31            12            0.16          0.05          .
   06/08/81                        0.17           31            280           1.06          0.46          .
   06/13/81                        0.52           31            16            0.18          0.05          .
   06/15/81                        0.09           78            12            0.12          0.05          .
   06/20/81                        0.19           31            88            0.2           0.1           .
   08/26/81                        .              31            21            0.12          0.05          .
   08/27/81                        .              31            8             0.06          0.05          .
   08/29/81                        .              19            12            0.08          0.05          .
   08/31/81                        .              19            10            0.1           0.05          .

SITE MEAN                          0.2211429      33.08837      37.91579      0.2129575     0.09133647    .
SITE COEFFICIENT OF VARIATION      0.767188       0.4085739     1.56177       0.987036      0.8642529     .

NUMBER OF EVENTS FOR THIS STATION       9

TOTAL NUMBER OF EVENTS                  755
```

APPENDIX C

DATA ANALYSIS METHODOLOGIES

APPENDIX C
DATA ANALYSIS METHODOLOGIES

In order to assemble and analyze the data being developed by the NURP projects and determine and interpret results, it was necessary for NURP to use a set of consistent analytical methodologies. By and large, the methodologies that were selected were developed under different EPA efforts, many under the sponsorship of the Office of Research and Development. Following the areas of project emphasis, Appendix C-1 presents for urban runoff loads, C-2 for receiving water impacts, and C-3 for effectiveness of controls, the adopted methodologies and their supporting logic.

C-1. URBAN RUNOFF LOADS

The constituents found in urban runoff are highly variable, both during an event, as well as from event to event at a given site and from site to site within a given city and across the country. This is the natural result of high variations in rainfall intensity and occurrence, geographic features that affect runoff quantity and quality, and so on. Therefore, a method of expressing the size of an urban runoff load and its variability was needed. The event mean concentration, defined as the total constituent mass discharge divided by the total runoff volume, was chosen as the primary statistic for this purpose, and event mean concentrations were calculated for each event at each site in the accessible data base. If a flow-weighted composite sample was taken, its concentration was used to represent the event mean concentration. On the other hand, if sequential discrete samples were taken over the hydrograph, the event mean concentration was determined by calculating the area under the loadograph (the curve of concentration times discharge rate over time) and dividing it by the area under the hydrograph (the curve of runoff volume over time). For the purpose of determining event mean concentrations, rainfall events were defined to be separate precipitation events when there was an intervening time period of at least six hours without rain. Given this data base of Event Mean Concentrations (EMCs), there are a number of questions that must be answered in order to extract information that will be useful for water quality planning purposes, including: What is the underlying population distribution and what are the appropriate measure of its attributes, e.g., central tendency, variability, etc.? Do distinct subpopulations exist and what are their characteristics? Are there significant differences in data sets grouped according to locations around the county (geographic zones), land use, season, rainfall amount, etc.? How may these variations be recognized? What is the most appropriate manner in which to extrapolate the existing data base to locations for which there are no measurements?

These questions have not all been answered as of this preliminary report. This appendix will outline the procedures used to analyze the problem to date and projected future work during the remainder of the project. There will be no attempt to explain standard statistical procedures since these are readily available in the literature. Nor will the operation of the SAS computer statistical routines be explained since they are available almost universally at computer centers. However, the relevant procedures used by the NURP team will be described.

LOG-NORMALITY

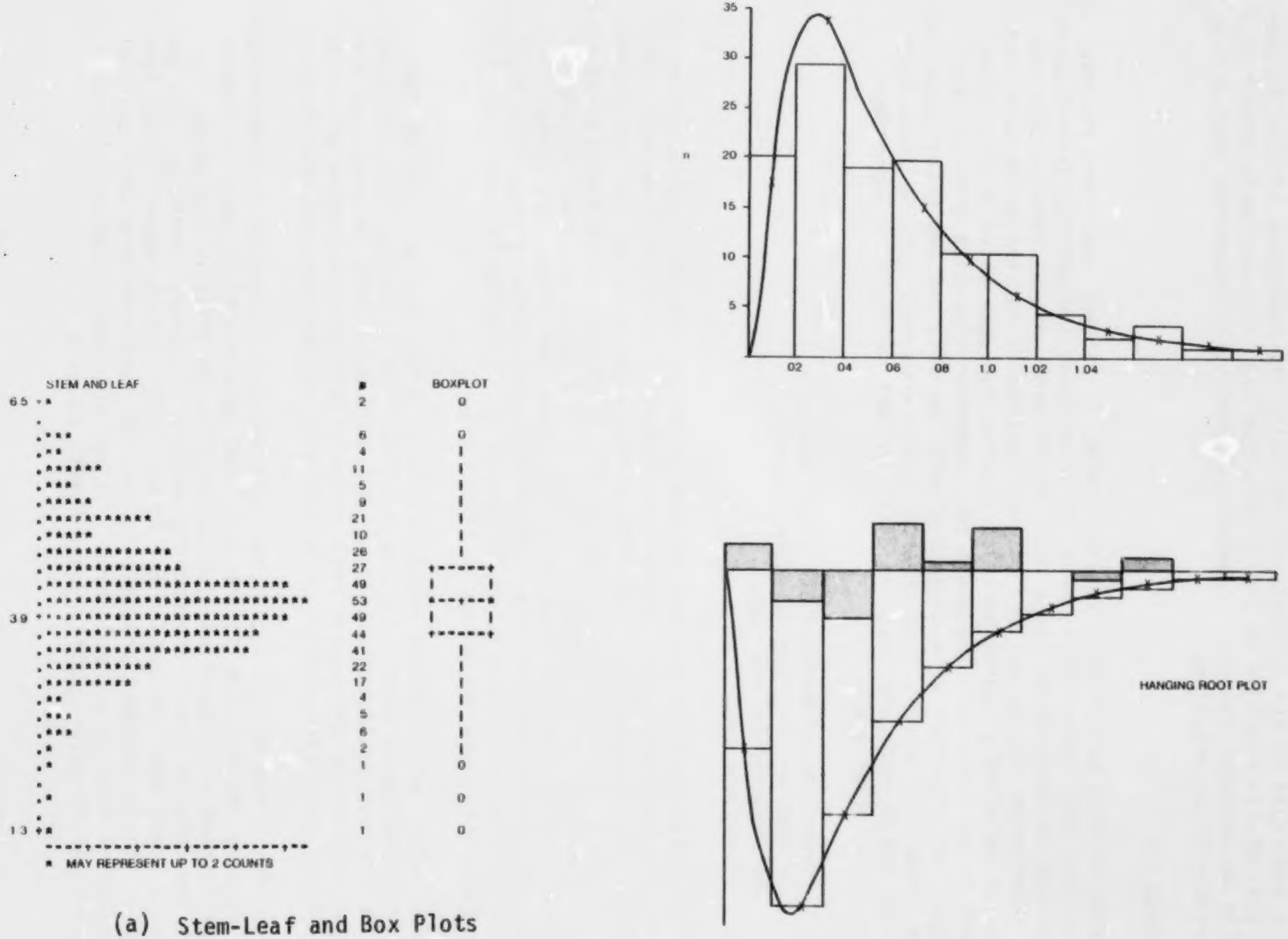
When working with highly variable data, it is very important to know, at a prescribed confidence level, what the underlying probability distribution is (as opposed to assuming or guessing). Based upon natural expectations and prior experience, it was decided to test whether or not the event mean concentration data had a log-normal distribution for each water quality constituent to be examined. The event mean concentration data from all NURP projects' loading sites were collected into one data set and transformed into natural logarithm space. Four separate procedures were used to judge log-normality and to indicate that the data, in fact, will fit a log-normal distribution. They are:

1. Inspection of basic statistical measures
2. Inspection of graphical data displays
3. Kolomogorov-Smirnov test
4. Chi-square test

The first two procedures are qualitative in nature and rely upon experienced professional judgement. For inspection of basic statistical measures, one transforms the data into the logarithmic domain and examines the calculated values of mean, median, mode, kurtosis, etc. with what would be expected from a normal (Gaussian) distribution. Graphical data displays used include cumulative probability distribution plots, stem-leaf plots, box plots, hanging-root plots, and the like. Examples of cumulative probability distribution in log space were given in Chapter 5. Examples of stem-leaf, box and hanging root plots are given in Figure C-1.

The latter two tests are quantitative in nature and were run at the 95 percent confidence level (i.e., $\alpha = 0.05$). The Kolmorogov-Smirnov test is based upon the maximum deviation of the test data from the expected distribution, while the Chi-square test is based upon the cumulative deviation of the actual test data distribution from that of the expected distribution.

The importance of the log-normal determination cannot be overemphasized. Among its many implications is the fact that determinations made in simple arithmetic space with Gaussian assumptions will be invalid, the geometric mean of the data is a more appropriate measure of central tendency than the arithmetic mean, etc. (Aitchison and Brown, 1969). With regard to the latter, it is fairly standard practice to use the geometric mean when dealing with bacterial data (e.g., coliforms); it has not been so universally applied to other types of water quality constituents to date.



(a) Stem-Leaf and Box Plots

(b) Hanging Root Plot

Figure C-1. Steam and Leaf, Box, and Hanging Root Plots

DETECTION OF SUB-POPULATION DIFFERENCES

Although a data set may strongly exhibit a log-normal distribution, it still may be made up of a number of sub-populations, and identification of those might help to explain some of the variance present in the data. The key question to be answered is: Do different log-normal populations (i.e., different mean and/or variance) exist within the pooled population, and if so, how may homogeneous sub-populations be determined (e.g., how may the data be grouped into subsets)? Even if they are log-normal, sub-populations of data may differ because of; (1) differing means, (2) differing variances, or (3) both, as suggested in Figure C-2. For each parameter, the NURP data set consists of up to 100 sites ("treatments" in statistic parlance) with a varying number of observations (storms), on the order of 5 - 20, at each site. Even with the considerable advantage of normality of the logarithms of the EMC's, the general question of how to test the hypothesis of homogeneity of sample means and variances is unresolved in statistics. The procedure used for this draft report is outlined below, along with proposed future analysis.

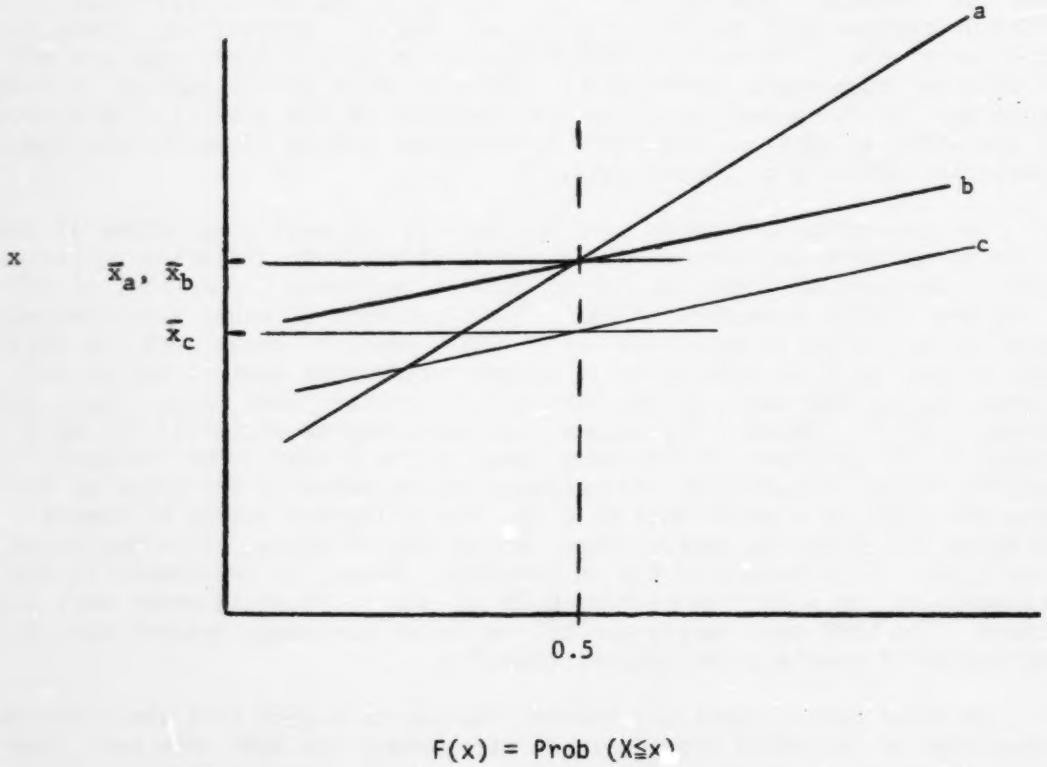


Figure C-2. Populations a and b have different variances. Populations b and c have different means. Populations a and c differ in both mean and variance.

The standard procedure for testing of homogeneity of sample means is analysis of variance (ANOVA) and its resulting F-test. Three basic assumptions are inherent in the ANOVA procedure:

1. Each sub-population (treatment) is normally distributed,
2. Each sub-population (treatment) has the same variance, and
3. All samples are independent.

Strictly speaking, the assumptions refer to the error term in the ANOVA model, but they are commonly applied to the data themselves. The NURP data generally fulfill assumptions (1) and (3) quite well, but assumption (2), equality of variances, is not necessarily true. In fact, it is one of the conditions upon which to test the hypothesis of homogeneity of population distributions.

Fortunately, ANOVA is not highly sensitive to deviations from assumptions (1) and (2) as long as the sample size is "relatively large" and the number of samples in each sub-population is "approximately the same". These conditions are met in a quantitative sense for most comparisons, although unequal sample sizes are a problem for some, notably sub-populations based on land use. However, the fact of insensitivity is the basic justification for ANOVA procedures used for this preliminary report. Fortunately, there is no question of the validity of independence of EMC values since they are all derived from independent storm events. (Violation of the assumption of independence may result in serious errors in inference of the results.) A discussion of the ANOVA assumptions and their consequences may be found in many standard statistics books, e.g., Hays (1981).

The assumption of homogeneous variance is the most troublesome of the three since there undoubtedly are sub-populations with differing variances. Indeed, the Bartlett test was run on several variables (logarithms of EMC's) using the DISCRIM procedure of SAS. The hypothesis of equal variances was rejected at a significance level of 0.0001. However, because of the robustness of the ANOVA procedure, it is seldom recommended that it not be performed just on the basis of the Bartlett or similar tests (e.g., Hays, 1981; Lindman, 1974). Rather, the unequal variances may be accounted for by a change in the apparent significance level of the F-test. For instance, Scheffé (1959) illustrates this effect when an ANOVA is performed at an apparent level of significance of 0.05. For different ratios of sample variance and differing sample sizes, actual significance levels may range from 0.025 - 0.17 (Table 10.4.2 in Scheffé). Hence, an adjustment in the assumed level of significance from 0.05 to, say, 0.10 would cover most situations. The NURP data rarely exhibit ratios of variances greater than 2:1 and ratios of sample sizes greater than 3:1.

In other words, there are several reasons to expect that the classical robustness of the ANOVA procedure will accomodate the NURP data set. However, there are other theoretical options, albeit, inconvenient.

When sub-populations (treatments) are compared pair-wise, an inference may be attempted on the equality of means, given that their variances are unequal. This is known in the statistics literature as the Behrens-Fisher problem (Winer, 1971) for which a completely satisfactory sampling distribution is not yet agreed upon. A common approach is to compute an approximate t-statistic whose degrees of freedom are obtained by the Satterthwaite approximation technique. This can be done in SAS using the TTEST procedure. Unfortunately, for a pairwise comparison of all combinations of, say, 100 sites, $\binom{100}{2} = 4950$ separate runs would need to be made, infeasible as of this first report. In order to achieve a significance level of 5 percent for the entire family of 4950 tests, Bonferroni (Neter and Wasserman, 1974) specifies that the significance level, α_0, of each test should be determined as $\alpha_0 = 0.05 \div 4050 = 0.000010101$. Clearly, a disadvantage of this procedure is that the individual tests become so conservative that any differences that actually exist would frequently fail to be detected. A variation on this procedure may be possible in the future if sub-groupings of fewer than all the individual sites can be determined satisfactorily.

SUB-GROUPINGS

To date, sub-groupings of site data have been made a priori on the basis of fundamental hydrologic and water quality considerations. These attributes have been: geographical location or zone, land use, season, and magnitude of rainfall event. At least two questions will be addressed in this subsection: (1) Can groupings be proposed on another basis, and (2) how can these sub-groups themselves be grouped into similar sub-populations.

Concerning the former question, it is a legitimate part of an experimental design to group "treatments" into like categories on a rational, physical basis. In part, for this first report, this was the only option available, and reflects conventional engineering wisdom. Previous studies have shown differences on the basis of region and land use. The NURP efforts to date are the first to investigate the effect, on a large scale, of season and storm magnitude.

In the future, it will be useful to perform a grouping in an "unbiased" manner, in which preconceived notions of groupings may be avoided. These groupings may then be compared with those enumerated above to see if they agree with physical reasoning. One method for this is cluster analysis, in which sub-groups with similar attributes (e.g., mean and variance) may be grouped together into "clusters". These clusters may be examined for similar physical attributes (e.g., region, land use) and a regular ANOVA performed to detect differences in means. Additional future work will include regression and correlation procedures utilizing the NURP fixed-site data base for additional physical insight into cause and effect relationship among EMC's and independent variables. Ultimately, selection of the appropriate lognormal distribution for a study area can be done on a causative basis, rather than a priori on purely statistical groupings.

Once again, there is not statistical consensus on a method for selecting groups of sub-populations when their variances as well as their means may differ. However, several procedures are available for multiple comparisons of means, usually under the assumption of equal variances. These are described, for instance, by Winer (1971) and Chew (1977). The most common procedure is that of Duncan, in which means are ranked and placed into one or more groups with other means. The Duncan test (available on SAS) is among the more discriminating multiple comparisons procedures in terms of finding differences (Winer, 1971). That is, compared to certain other available tests, it will tend to provide more separate groupings. Because of its wide acceptance and because it can be modified to handle unequal sample sizes, it has been used to date for grouping of subpopulations. In the future, alternative procedures may also be used for comparison.

REFERENCES

Aitchison, J. and J. A. C. Brown, The Log-Normal Distribution, Cambridge at the University Press, 1969.

Chew, V., "Comparisons Among Treatment Means in an Analysis of Variance", Publication ARS/H/6, USDA, Hyattsville, MD, 1977.

Hays, W. L., Statistics, Third Edition, Hold, Rinehart and Winston, 1981.

Lindman, H. R., Analysis of Variance in Complex Experimental Design, W. H. Freeman, 1974.

Neter, J. and W. Wasserman, Applied Linear Statistical Models, Richard D. Irwin, Inc., 1974.

Scheffé, H. A., The Analysis of Variance, Wiley, 1959.

Winer, B. J., Statistical Principles in Experimental Design, Second Edition, McGraw Hill, 1971.

C-2. RECEIVING WATER IMPACTS

This section presents a description of the methods used to evaluate the receiving water quality impacts of urban runoff. Because of the important differences in behavior, separate methods have been adopted for rivers and streams and for lakes. It is anticipated that a technique for evaluating estuaries as a third class of receiving waters will be developed. However, this preliminary NURP report does not include the estuary analysis methods.

RIVERS AND STREAMS

The approach adopted to quantify the water quality effects of urban runoff for rivers and streams focuses on the inherent variability of the runoff process. What occurs during an individual storm event is considered secondary to the overall effect of a continuous spectrum of storms from very small to very large. Of basic concern is the probability of occurrence of water quality effects of some relevant magnitude.

Urban runoff is characterized by relatively short duration events with relatively large time periods between events. On a national average basis, the median rainstorm duration is about 4.5 hours with a time between storm midpoints of about 60 hours. In addition to this temporal intermittance, urban runoff events are highly variable in magnitude.

To consider the intermittent and variable nature of urban runoff, a stochastic approach was adopted. The method involves a direct calculation of receiving water quality statistics using the statistical properties of the urban runoff quality and other relevant variables. The approach uses a relatively simple model of the physical behavior of the stream or river (as compared to many of the deterministic simulation models). The results are therefore approximations.

The theoretical basis of the technique is quite powerful as it permits the stochastic nature of runoff process to be explicitly considered. (Simulation is in many cases costly or cumbersome in this regard.) Application is relatively straightforward, and the procedure is relevant to a wide variety of cases. These attributes are particularly advantageous given the national scope of the NURP Project. The details of the stochastic method are presented below.

Basic Approach

Figure 1 contains an idealized representation of urban runoff discharges entering a stream. The discharges usually enter the stream at several locations but can be aggregated into an equivalent discharge flow which enters the system at a single point. The equivalent discharge flow (QR) is the sum of the individual discharges, and the equivalent concentration (CR) is the slow-weighted mean concentration for the constituent of concern. If the mass discharged from each individual site is known for a storm event, the mean concentration is the total mass divided by total flow.

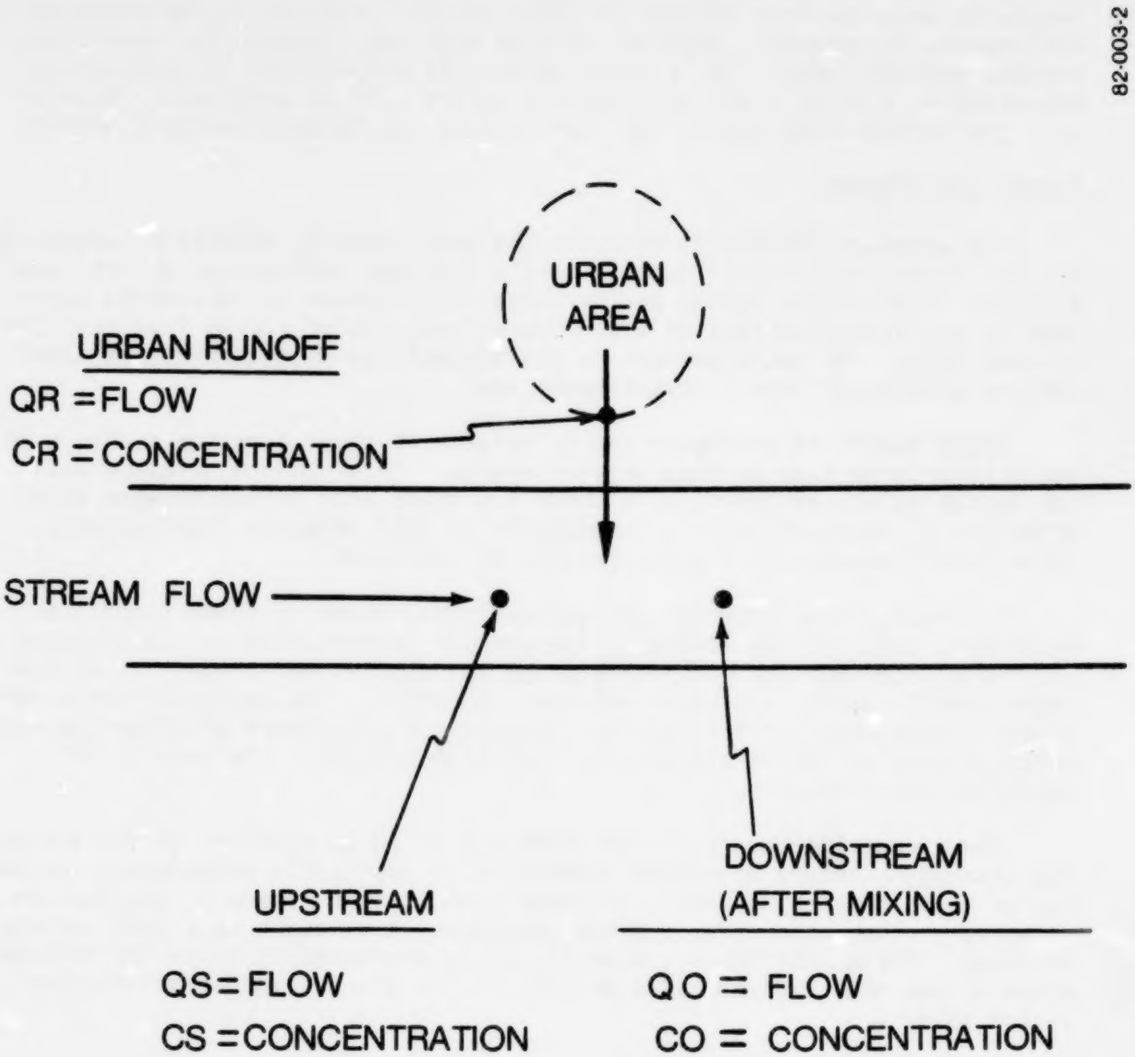


Figure 1. Idealized Representation of Urban Runoff Discharges Entering a Stream

40

Receiving water concentration (CO) is the resulting concentration after complete mixing of the runoff and stream flows, and should be interpreted as the storm-event mean concentration just downstream of all of the discharges as shown in Figure 1. The four variables that determine the stream concentration (CO) are:

- Urban runoff flow (QR)
- Urban runoff concentration (CR)
- Stream flow (QS)
- Stream concentration (CS)

For an individual rainfall/runoff event, it is possible, in principle, to measure each of the relevant variables independently. From those, the average stream concentration (CO) is calculated:

$$CO = \frac{(QR\ CR) + (QS\ CS)}{QR + QS} \qquad (1)$$

If a dilution factor, ϕ, is defined as:

$$\phi = \frac{QR}{QR + QS} \qquad (2)$$

CO may be defined in terms of ϕ by:

$$CO = [\phi\ CR] + [(1-\phi)\ CS] \qquad (3)$$

The calculated value of the downstream concentration (CO) for an individual event could be compared to a water quality standard (CL), or to any other stream concentration which relates water quality to protection or impairment of beneficial water use. If the comparisons of CO and CL indicate that water quality is satisfactory, then it may be assumed that the individual event would not impair beneficial water usage. By contrast, if the comparison of CO and CL indicates that during this event receiving water concentrations of the constituent in question would not protect beneficial usage, the relative contributions of runoff and upstream sources to the violation could be ascertained from Equation (3) as follows:

$$CO = \overbrace{[\phi \quad CR]}^{\text{Runoff}} + \overbrace{[(1-\phi) \quad CS]}^{\text{Upstream}}$$

In principle, this procedure could be repeated for a large number of rainfall/runoff events. If this were done, the probability that CO violated the level CL during rainfall/runoff periods could be defined, and the relative contribution of runoff and upstream quality could also be estimated.

The basic approach adopted for the NURP project employs Equations (1) through (3) and the statistical properties of the four random variables (QR, CR, QS, and CS) to calculate the cumulative probability distribution of the downstream concentration (CO) during runoff events. From this, the probability of occurrence or frequency of any target concentration being equaled or exceeded can be computed.

An essential condition to the use of the approach is that each of the four variables which contribute to downstream receiving water quality can be adequately represented by a log-normal probability distribution. Examination of a reasonably broad cross-section of data indicates that log-normal probability distributions can adequately represent discharges from the rainfall/runoff process, the concentration of contaminants in the discharge, and the daily flow record of many rivers and streams. Further discussion of the use of log-normal distributions was presented earlier in this Appendix.

The approach developed can be applied on a site specific basis, or can be generalized and applied to a river system, region of the country, or a series of locations which are characterized by similar rainfall and stream flow distributions. The ratio of the stream drainage area (above the urban area) to the drainage area of the urban area is one of the useful factors which allows this generalization. The calculations discussed below consider a site specific application to illustrate the approach.

Statistical Calculations

The calculation procedure consists of a number of specific steps as presented in Table 1. The theoretical basis for the calculations is described below and consists of four components as follows:

a. Statistical equations of normal and log-normal random variables

b. Statistical properties of the dilution factor

c. Statistical properties of the downstream concentration

d. Probability of occurrence of selected stream concentrations

TABLE 1. CALCULATION PROCEDURE FOR STATISTICAL PROPERTIES OF STREAM CONCENTRATION

1. Calculate the estimated mean and variance of the logarithmic transforms of each of the four variables (QR, QS, CR, and CS).

2. Calculate the arithmetic mean and variance of the four variables. This calculation employes formulas that relate the arithmetic mean and variance to the mean and variance of the log transformations.

3. Calculate the mean and variance of the dilution factor (ϕ) employing the mean and variance of the logarithmic transforms of QR and QS. The calculation considers:

   - Possible correlations between upstream flow (QS) and runoff flow (QR).

   - Adjustments of the mean and variance of ϕ due to the upper bound of 1.0 on ϕ.

4. Calculate the arithmetic mean and variance of ϕ as in Step 2.

5. Calculate the mean and variance of CO using the estimates of the arithmetic mean and variance of CR, CS, and ϕ.

6. Plot the log-normal cumulative probability distribution of stream concentration, CO. The mean and variance of the logarithmic transforms are used in developing the plot.

7. Define CL from a water quality standard or use other criteria to define a target concentration limit which will provide protection of beneficial water use.

8. From the log-normal cumulative probability plot for CO, determine the probability corresponding to the selected value of CL.

9. Based on the basic probability value, compute the frequency or recurrence interval of water quality problems.

Statistical Equations for Normal and Log-Normal Random Variables

Using the pollutant concentration in the stormwater runoff as an example of the four basic random variables (QR, QS, CS being the other three), the following notation is used:

CR	is the random variable itself (runoff concentration).
CR'	is the log (base e) transformed random variable (ℓn runoff concentration).
$\widetilde{CR}$	is the arithmetic median of CR.
μ	refers to the mean (e.g., μCR, $\mu CR'$).
σ^2	refers to the variance (e.g., $\sigma^2 CR$, $\sigma^2 CR'$) (σ refers to the standard deviation).
ν	refers to the coefficient of variation of the arithmetic random variable (e.g., νCR).

Rationships between the arithmetic projections and the properties of a log-normal distribution are defined by:

$$\widetilde{CR} = \exp\ (\mu CR') \tag{4}$$

$$\nu CR = \sqrt{\exp(\sigma^2 CR') - 1} \tag{5}$$

$$\mu CR = \widetilde{CR}\ \ \exp(1/2\ \sigma^2 CR') \tag{6}$$

$$\sigma CR = \nu CR\ \ \mu CR \tag{7}$$

For a random variable such as CR which is distributed log normally, the value at the α percentile (CR_α) is defined as:

$$P[CR \leq CR_\alpha] = \alpha$$

$$CR_\alpha = \exp\ (\mu CR' + Z_\alpha\ \sigma CR') \tag{8}$$

where Z_α is the value of the standardized normal cumulative distribution, given in Table 2.

Statistical Properties of Dilution

For the dilution factor (ϕ) as defined in Equation (2), the value for any cumulative probability percentile is given by:

$$\phi_\alpha = \frac{\widetilde{QR}}{\widetilde{QR} + \widetilde{QS}\ \ \exp(Z_\alpha\ \ \sigma RS')} \tag{9}$$

TABLE 2. CUMULATIVE STANDARD NORMAL DISTRIBUTION

Probabilities for Values of z

z'	P(z < z')	z'	P(z < z')	z'	P(z < z')	z'	P(z < z')
-4.0	.0000	-2.0	.0228	0	.5000	2.0	.9772
-3.9	.0000	-1.9	.0287	.1	.5398	2.1	.9821
-3.8	.0001	-1.8	.0359	.2	.5793	2.2	.9861
-3.7	.0001	-1.7	.0446	.3	.6179	2.3	.9893
-3.6	.0002	-1.6	.0548	.4	.6554	2.4	.9918
-3.5	.0002	-1.5	.0668	.5	.6915	2.5	.9938
-3.4	.0003	-1.4	.0808	.6	.7257	2.6	.9953
-3.3	.0005	-1.3	.0968	.7	.7580	2.7	.9965
-3.2	.0007	-1.2	.1151	.8	.7881	2.8	.9974
-3.1	.0010	-1.1	.1357	.9	.8159	2.9	.9981
-3.0	.0013	-1.0	.1587	1.0	.8413	3.0	.9987
-2.9	.0019	- .9	.1841	1.1	.8643	3.1	.9990
-2.8	.0026	- .8	.2119	1.2	.8849	3.2	.9993
-2.7	.0035	- .7	.2420	1.3	.9032	3.3	.9995
-2.6	.0047	- .6	.2743	1.4	.9192	3.4	.9997
-2.5	.0062	- .5	.3085	1.5	.9332	3.5	.9998
-2.4	.0082	- .4	.3446	1.6	.9452	3.6	.9998
-2.3	.0107	- .3	.3821	1.7	.9554	3.7	.9999
-2.2	.0139	- .2	.4207	1.8	.9641	3.8	.9999
-2.1	.0179	- .1	.4602	1.9	.9713	3.9	1.0000

Values of z for Selected Probabilities

z'	P(z < z')	z'	P(z' < z')
-3.090	.001	0.6745	.750
-2.576	.005	1.282	.900
-2.326	.010	1.645	.950
-1.960	.025	1.960	.975
-1.645	.050	2.326	.990
-1.282	.100	2.576	.995
-0.6745	.250	3.090	.999

where the variables are defined as before and in addition $\sigma^2 RS'$ is the covariance between QR' and QS'. The covariance is computed as follows:

$$\sigma RS' = \sqrt{\sigma^2 QS' + \sigma^2 QR' - 2\rho RS' \ \ \sigma QS' \ \ \sigma QR'} \qquad (10)$$

$$\rho RS' = \frac{1}{N} \sum_{i=1}^{N} \frac{(QS'_i - \mu QS') \ \ (QR'_i - \mu QR')}{\sigma QS' \ \ \sigma QR'} \qquad (11)$$

where $\rho RS'$ is the correlation coefficient between runoff and stream flow and i refers to rainfall events 1, 2, 3 . . N.

The stream flow (QS) may be correlated to the runoff flow (QR) in some basins since rainfall patterns which cross the drainage area above the urban area will tend to produce increases in stream flow as well as runoff. For such systems, larger runoff discharges will tend to be associated with larger stream flows. The correlation coefficient ($\rho RS'$) accounts for this tendency.

Because the dilution during runoff periods has an upper bound of 1, its probability distribution is in general not log-normal, even with log-normal runoff and stream flow. The actual distribution deviates from log-normal at the extremes sufficiently to require the use of a numerical technique to integrate the actual distribution, or one may use a log-normal approximation over the probability range of interest. At this point in the NURP Project, a log-normal approximation, as described below, has been used for the probability distribution of ϕ. This permits CO to follow a log-normal distribution, which has a number of useful properties.

An estimate of the log-mean dilution may be obtained by interpolating between selected α and $(1 - \alpha)$ percentile values using Equation (9) and the following:

$$\mu\phi' = \frac{1}{2} \left(\phi'_\alpha + \phi'(1-\alpha)\right) \qquad (12)$$

The log standard deviation of dilution may be estimated by the following formula, which, in effect, determines the slope of the straight line on the log probability plot:

$$\sigma\phi' = \frac{1}{2Z_\alpha} \left(\phi'(1-\alpha) - \phi'_\alpha\right) \qquad (13)$$

Note that Equations (11) and (12) are valid for $\alpha > 50$ percent. To insure that the estimated dilution falls between 0 and 1.0 somewhat beyond the 95 percentile, the 90 percent interval bounded by α equal to 90 and 1- equal to 5 percent was selected. While the errors introduced by this approximation will not change the general outcome of the probability estimates, they may be important in certain cases and are currently being investigated. Having estimated the log statistics of dilution, Equations (4) through (7) can be used to compute the arithmetic statistics.

Statistical Properties of Stream Concentration

The statistics of upstream concentration (CS), urban runoff concentration (CR), and dilution (ϕ) can be used to compute the statistics of the receiving water concentration just downstream of the urban discharge (i.e., immediately after mixing). The arithmetic mean is defined by:

$$\mu CO = [\mu CR \quad \mu\phi] + [\mu CS \quad (1 - \mu\phi)] \tag{14}$$

The arithmetic standard deviation of the stream concentration is defined by:

$$\sigma CO = \sqrt{\sigma^2\phi\ (\mu CR - \mu CS)^2 + \sigma^2 CR\ (\sigma^2\phi + \mu^2\phi) + \sigma^2 CS\ (\sigma^2\phi + (1 - \mu\phi)^2)} \qquad (14)$$

The coefficient of variation is calculated by:

$$CO = \frac{\sigma CO}{\mu CO} \tag{16}$$

Based on Equations (4) through (7), the arithmetic statistics may be used to derive the log statistics as follows:

$$\text{log mean:} \quad \mu\phi' = \ln\left(\frac{\mu CO}{\sqrt{1 + \nu^2 CO}}\right) \tag{17}$$

$$\text{log standard deviation:} \quad \sigma\phi' = \sqrt{\ell n\ (1 + \nu^2 CO)} \tag{18}$$

From the log-statistics information on probability may be developed.

The Recurrence of Selected Stream Concentrations

The fundamental result of the statistical analysis is the derived cumulative probability distribution of stream event mean concentration; that is, the cumulative probability function F(CO). Graphically, this is shown in Figure 2. For a given concentration of interest (CL), the corresponding probability may be read directly from the plot (see Figure 2). Alternately, the value of CO at the α percentile is defined as

$$P = 1 - P[CO \leq CO_\alpha] = 1 - \alpha \tag{19}$$

$$CO_\alpha = \exp(\mu CO' + Z_\alpha\ \sigma CO^1) \tag{20}$$

One way of properly interpreting the probability (P) corresponding to a given concentration level is the long term average fraction of events with a stream event mean concentration equal to or exceeding the specified level. For example, a probability of 0.10 would specify that on average one in ten events have a stream event mean concentration equal to or greater than the specified value.

For the purposes of evaluation and interpretation, it would be useful to transform the basic probability statistic into a more meaningful or intuitive form. By combining the percent of storms which cause various concentrations to be exceeded with the average number of storms per year, a time-based reoccurrence relationship may be established as described below.

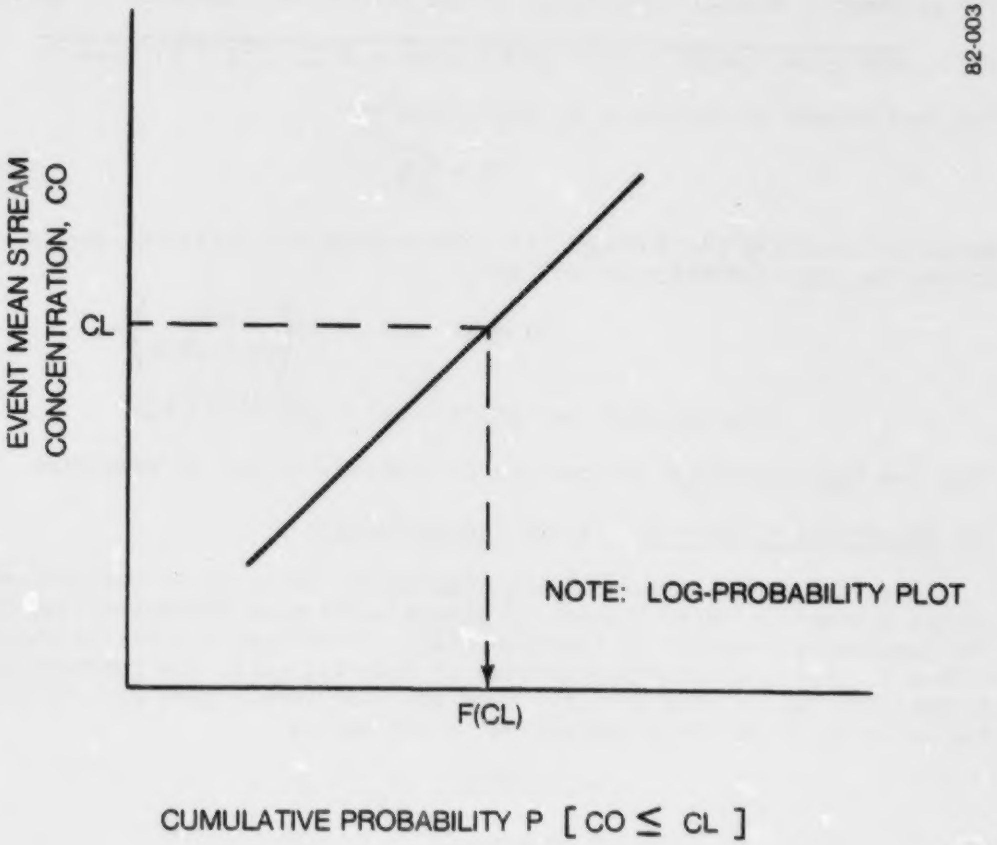


Figure 2. Example Cumulative Probability Distribution Function of Event Mean Stream Concentrations

48

Reccurrence is a definition based (generally) on the marginal distribution of random variables. Basically, if P is the probability of a value of magnitude CL being equaled or exceeded in a given time period, then the recurrence interval (R) defined as 1/P is the average number of time periods between exceedances.

Assuming as discussed above, we have the cumulative probability distribution function of event mean stream concentrations (i.e., F(CO)). Then:

$$P[CO \leq CL] = F(CL) \tag{21}$$

If we want annual recurrence, we need to find the probability that an event concentration of a given magnitude (CL) is equalled or exceeded in a year. The statement of the problem is:

$$P = 1 - P[CO_m \leq CL] = 1 - P[\max(CO_1 \ . \ . \ . \ CO_N) \leq CL] \tag{22}$$

where CO_m is the maximum event concentration in a year, and N is the number of events in a year. Assuming that event concentrations are independent and identically distributed with a known distribution such as log-normal, equation (22) becomes:

$$\begin{aligned} P &= P[CO \geq CL] = 1 - F^N(CL) \\ R &= \frac{1}{(1 - F^N(CL))} \end{aligned} \tag{23}$$

A first order approximation to this is given by:

$$R = \frac{1}{(1 - F(CL))\ N} \tag{24}$$

As a convenient and meaningful way to interpret the basic probability results, the average recurrence interval as defined in Equation (24) was adopted. A schematic example of the relationship is shown in Figure 3.

LAKES

The impact of urban runoff on lakes may be determined by calculating eutrophication parameters in the lake (i.e., total phosphorus concentration, chlorophyll a concentration, and secchi depth) due to the urban runoff and comparing these values to desired levels. Total phosphorus is the prime variable of interest, with in-lake concentrations calculated using the Vollenweider method. Chlorophyll-a and secchi depth, as well as sediment oxygen demands, are estimated based on available regression equations relating these variables to total phosphorus. For ease of classification, the area ratio (α) defined as the ratio of the urban drainage area to the lake surface area, will be expressed in terms of the eutrophication parameters.

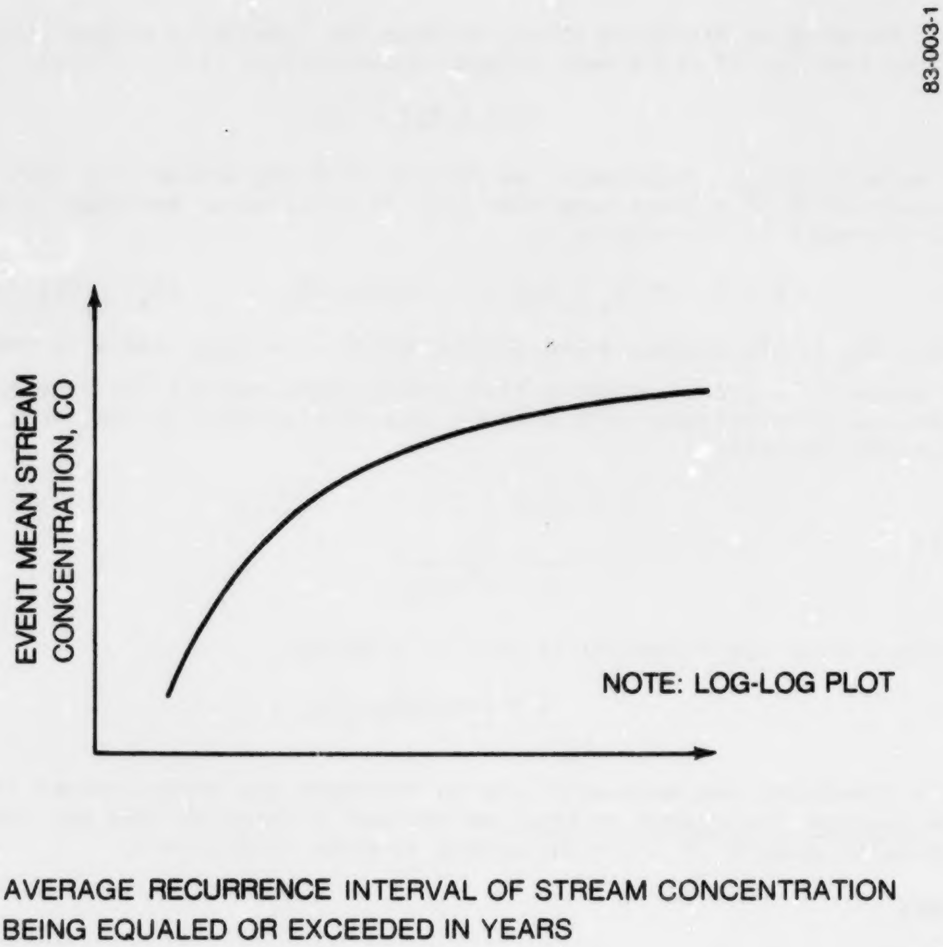


Figure 3. Example of the Average Recurrence Interval as a Function of Event Mean Stream Concentration

Relationship Between Area Ratio (α) and Lake Total Phosphorus Concentratio

The relationship between the area ratio and the in-lake total phosphorus concentration may be derived for the case where the urban runoff represents the sole source of the total phosphorus loading into the lake. The method proposed by Vollenweider is as follows (1, 2, 3, 4):

$$\bar{p} = \frac{W'}{(H/\tau) + v_s} \qquad (1)$$

where,

$\bar{p}$ = total phosphorus concentration ($g/m^3 = mg/l$)

W' = annual area loading rate (g/m^2 per yr)

H = average lake depth (m)

τ = hydraulic detention time (yr)

v_s = net settling velocity of TP (m/yr)

Rearranging Equation (1) yields:

$$W' = \frac{W}{A_\ell} = \left(\frac{p}{1000}\right)\left(\frac{H}{\tau} + v_s\right) \qquad (2)$$

where,

W = loading rate of TP (g/yr)

A_ℓ = lake surface area (m^2)

p = lake TP concentration ($\mu g/l$)

For the case where total phosphorus loading is generated by the runoff from the urban area:

$$W = Q_R \, C_R \, 3.15 \times 10^7 \qquad (3)$$

where,

Q_R = average annual urban runoff flow (m^3/sec)

C_R = average annual total phosphorus concentration (mg/ℓ)

and 3.15×10^7 is the factor to convert W to the units of (g/yr).

A runoff coefficient method may be used to relate the flow (Q_R) to rainfall as follows:

$$Q_R = C_v \, I \, A_d \, 3.17 \times 10^{-10}. \qquad (4)$$

where,

Q_R = average flow as above (m^3/sec)

C_v = average annual runoff to rainfall ratio

I = average annual precipitation (cm/yr)

A_d = urban drainage area (m^2)

Substituting Equation (4) into Equation (3) yields:

$$W = 0.1\ C_v\ I\ A_d\ C_R \qquad (5)$$

Substituting Equation (5) in Equation (2) yields:

$$\frac{W}{A_\ell} = .01\ C_v\ I\ C_R\ \frac{A_d}{A_\ell} = \frac{p}{1000}\ \frac{H}{\tau} + v_s$$

Rearranging and defining the area ratio $\alpha = \frac{A_d}{A_\ell}$ results in:

$$\alpha = \beta\ p(\frac{H}{\tau} + v_s) \qquad (6)$$

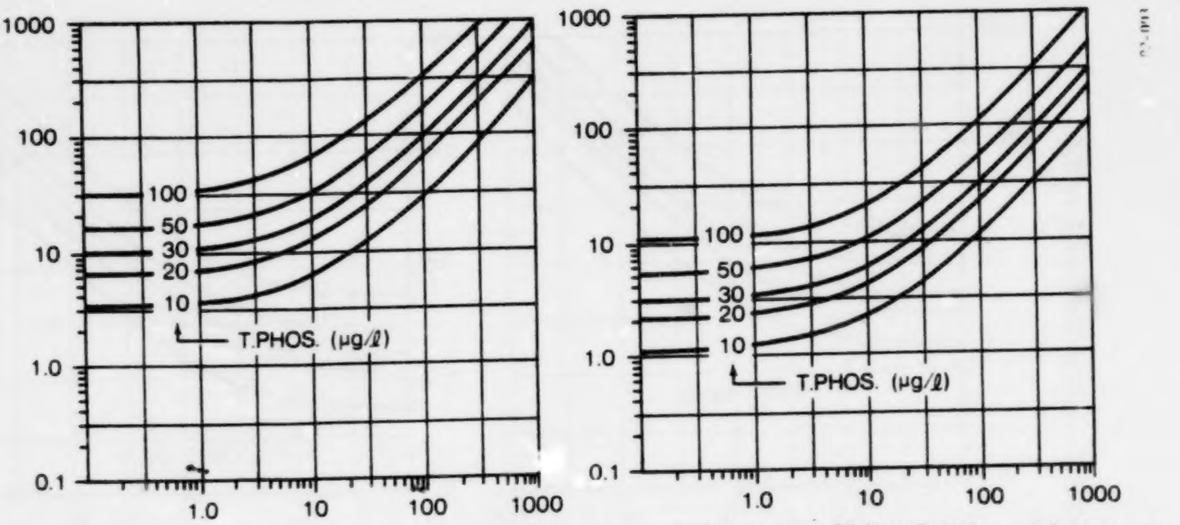
where,

$$\beta = \frac{1}{10\ C_v\ I\ C_R} \qquad (7)$$

Thus for given rainfall (I), runoff/rainfall ratio (C_v), and runoff quality (C_R) data, the quantity β is calculated from Equation (7). Using this value in Equation (6), the area ratio (α) is calculated directly as a function of the in-lake TP concentration (p, in μg/l) for a given lake geometry and residence time (H, τ). Alternately, for a desired maximum total phosphorus concentration, the maximum value of the ratio of the urban area to the lake surface area can be determined.

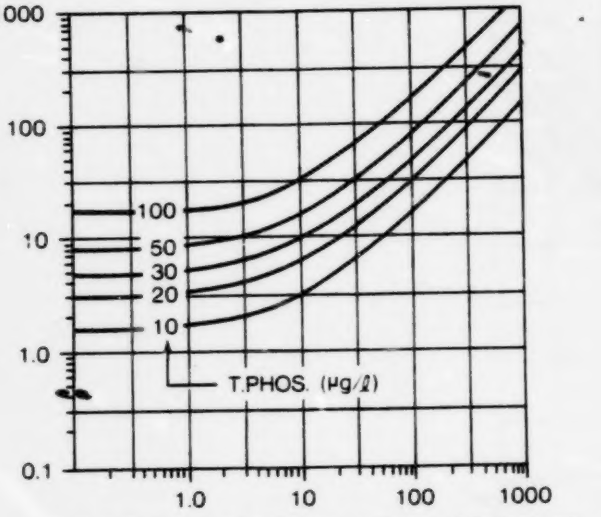
Graphs of Area Ratio (α) for Selected Rainfall and Runoff Conditions

Based on Equations (6) and (7), graphs of the area ratio versus the lake characteristic (H/τ) are presented in Figure 4 for commensurate ranges of the values of total phosphorus. Graphs are shown for two values of the net settling velocity of total phosphorus (v_s) = 10 m/yr used by Vollenweider (3) and 5 m/yr. As discussed by Thomann (7), the latter value may be more representative of shallow lakes (depths less than 3 meters) where resuspension may be significant. Three annual rainfalls of 12, 24, and 36 inches (30, 61 and 91 centimeters, respectively) are used to allow for regional variations. For all graphs, values of the average concentration of total phosphorus in the urban runoff is equal to 0.35 mg/ℓ, and the volumetric runoff to rainfall ratio is equal to 0.3.



(a) RAINFALL OF 12 IN/YR AND v_s OF 10 M/YR

(c) RAINFALL OF 36 IN/YR AND v_s OF 10 M/YR

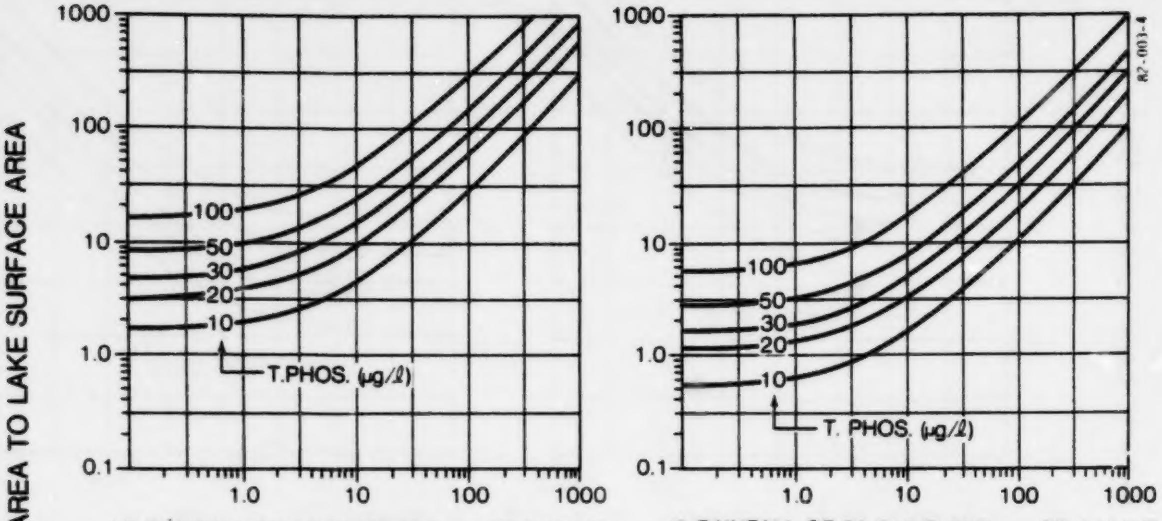


(b) RAINFALL OF 24 IN/YR AND v_s OF 10 M/YR

H/τ - LAKE DEPTH HYDRAULIC DETENTION TIME (M/YR)

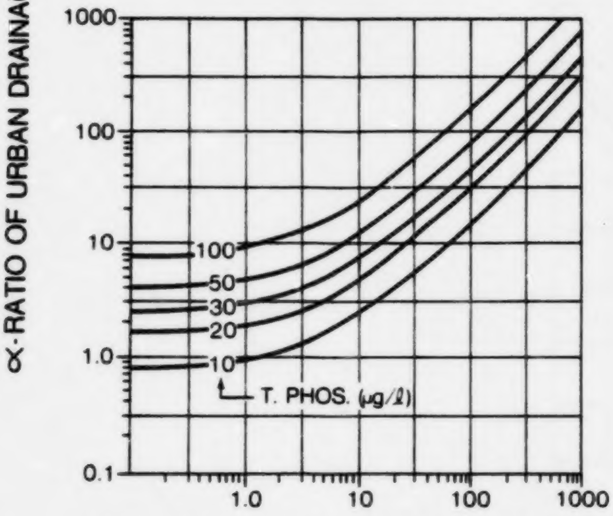
Figure 4. Graphs of Area Ratio Versus Lake Characteristics (H/τ)

53



(d) RAINFALL OF 12 IN/YR AND v_S OF 5 M/YR

(f) RAINFALL OF 36 IN/YR AND v_S OF 5 M/YR



(e) RAINFALL OF 24 IN/YR AND v_S OF 5 M/YR

Figure 4. Graphs of Area Ratio Versus Lake Characteristics (H/τ) (Cont'd)

The average total phosphorus concentration was derived from data gathered in NURP projects nationwide. Based on pooled data from the current NURP data base (i.e., 13 cities, 51 sites, 737 events) the average total phosphorus concentration was calculated to be 0.35 mg/l.

The parameters for each graft in Figure 4 are as follows:

Fig	v_s (m/yr)	I (in/yr)	C_v (in/in)	C_R (mg/l)
a	10	12	0.3	0.35
b	10	24	0.3	0.35
c	10	36	0.3	0.35
d	5	12	0.3	0.35
e	5	24	0.3	0.35
f	5	36	0.3	0.35

For these parameters, β as defined by Equation (7), is only a function of the rainfall and equals 0.0315, 0.0157 and 0.0105 for annual rainfalls of 12, 24 and 36 inches, respectively.

For any specific lake where data are available, local rainfall and runoff (volumetric runoff coefficient and runoff quality) data should be used to calculate β according to Equation (7). In addition, in-lake TP concentrations and TP mass inputs should be used to select the net settling velocity of total phosphorus for the lake.

Area Ratio (α) vs. Chlorophyll, Secchi Depth, and Sediment Oxygen Demand

In order that eutrophication measures other than total phosphorus may be used to establish limiting urban area ratios, regression equations between total phosphorus and the additional variables are used.

For chlorophyll-a, the regression equation according to Dillon and Rigler (5) is used since it is based on a wide range of chlorophyll a and total phosphorus data (TP $\leq$ 200 μg/l, Chl-a $\leq$ 260 μg/l);

$$\log_{10} \text{Chl-}\underline{a} = 1.449 \log_{10} p_s - 1.136 \qquad (8)$$

where,

Chl a = chlorophyll-a concentration (μg/l)

p_s = average total phosphorus concentration for the spring period (mg/l)

Letting $p_s = 0.9p$, where p is the average concentration for the summer period, and rearranging, p is expressed as:

$$p = 6.76 \times 10^{0.690 \log_{10}\text{CHl-}\underline{a}} \qquad (9)$$

Substituting Equation (9) into Equation (6) results in an expression for the area ratio (α) as a function of the chlorophyll-a concentration:

$$\alpha = \beta \, (6.76 \times 10^{0.690 \log_{10}\text{Chl-}\underline{a}}) \, ((H/\tau) + v_s) \qquad (10)$$

The expression relating secchi depth to total phosphorus concentration is from Rast and Lee (6):

$$\log_{10}Z = -0.359 \log_{10}p + 0.925 \qquad (11)$$

where,

Z = the secchi depth (m)

Solving Equation (11) for p and substituting into Equation (6) yields

$$\alpha = \beta \quad (380 \times 10^{-2.79 \log_{10}Z}) \, ((H/\tau) + v_s) \qquad (12)$$

For sediment oxygen demand Rast and Lee (6) report:

$$\log_{10}S_b = 0.467 \log_{10}p - 1.07 \qquad (13)$$

where,

S_b = the sediment oxygen demand (g/m² per day)

Solving Equation (13) for p and substituting into Equation (6) yields:

$$\alpha = \beta \cdot (195 \times 10^{2.14 \log_{10}S_b}) \, ((H/\tau) + v_s) \qquad (14)$$

Although the sediment oxygen demand is not a direct measure of eutrophication, it can be used to calculate dissolved oxygen concentrations in the hypolimnion when reaeration rates and vertical transport coefficients are available or may be estimated. Equations (11) and (13) are valid up to a maximum total phosphorus concentration of approximately 100 μg/l.

Graphs of the area ratio versus the lake characteristic (H/τ) may be developed for chlorophyll-a, secchi depth, and sediment oxygen demand using Equations (10), (12), and (14), respectively (see Figure 4 for the total phosphorus graphs).

References

1. Vollenweider, R. A., "The Scientific Basis of Lake and Stream Eutrophication, With Particular Reference to Phosphorus and Nitrogen as Eutrophication Factors," Tech. Rep. OECD, Paris, DAS/CSI/68, 27, 1968.

2. Vollenweider, R. A., "Moglichkeiten und Grenzen elementarer Modelle der Stoffbilanz von Seen" (Possibilities and Limits of Elementary Models Concerning the Budget of Substances in Lakes), Arch. Hydrobiol. 66, 1969.

3. Vollenweider, R. A., "Input-Output Models with Special Reference to the Phosphorus Loading Concept in Limnology," Schweiz. J. Hydrol. 37, 1975.

4. Vollenweider, R. A., "Advances in Defining Critical Loading Levels for Phosphorus in Lake Eutrophication," Mem. Inst. Ital. Idrobiol., 33, 1976.

5. Dillon, P. J., and Rigler, F. H., "The Phosphorus-Chlorophyll Relationship in Lakes," Limnology and Oceanography, Vol. 19 (5), September, 1974.

6. Rast, W., and Lee, G. F., "Summary Analysis of the North American (US Portion) OECD Eutrophication Project: Nutrient Loading-Lake Response Relationship and Trophic State Indices," for USEPA, ORD, Corvallis, Oregon ERL, EPA-600/3-78-008, January 1978.

7. Thomann, R. V., "The Eutrophication Problem", in Waste Load Allocation Seminar Notes, prepared by Manhattan College for USEPA, Washington, D.C.; August, 1981.

8. Hydroscience, Inc., "A Statistical Method for the Assessment of Urban Stormwater," for USEPA, Office of Water Planning and Standards, Washington, D.C. EPA 440/3-79-023, May, 1979.

9. Di Toro, D. M., Mueller, J. A., and Small, M. J., "Rainfall-Runoff and Statistical Receiving Water Models," Task Report 225 of NYC 208 Study prepared by Hydroscience, Inc., for Hazen and Sawyer, Engineers and the New York City Department of Water Resources, March 1978.

10. Hazen and Sawyer, Engineers, "Storm/CSO Laboratory Analyses", Task Report 223, Volume I and II of NYC 208 Study, prepared for the New York City Department of Water Resources, 1978.

C-3. EFFECTIVENESS OF CONTROLS

EFFECTIVENESS OF STREET SWEEPERS

Precipitation Statistics and Sweeping Intervals

Street sweeping operations are set up for a fixed interval, e.g., sweep once per week. If the average time between rainfall events is much less than the sweeping interval, then much of the material would be washed away by the rain. Hence, the street sweepers would be relatively ineffective. It helps to examine the rainfall statistics in the study area. Table 1 summarizes runoff statistics for four U.S. cities for which these data are available. The national average values, used in this interim report, provide rough estimates of the size of runoff events, the time between storms and the number of events per year. These numbers will be refined as the study progresses.

The results indicate a mean runoff per event of 0.12 inches. The time between storms is about three to four days. Correspondingly, about 100 storm events per year can be anticipated.

The coefficient of variation is the standard deviation divided by the mean. If the probability distribution is assumed to be a log normal, then the cumulative probability distribution can be estimated directly. The solutions for coefficients of variation of 1.0 and 1.5 are shown in Figure 1. This figure can be used to estimate, say, the percent of runoff events larger than 0.24 inches. From Table 1, the mean runoff event is 0.12 inches. Thus, the events of interest are those which are at least twice the mean runoff. From Figure 1, for $y/\bar{y} = 2.0$ and a coefficient of variation = 1.5. (from Table 1), 12% of the runoff events are greater than or equal to 0.24 inches.

Table 2 summarizes the statistics on the expected frequency of times between rainfall events for these four U.S. cities. On a national average, over

Table 1. Twenty-Five Year Rainfall Statistics For Four U.S. Cities; Source: Driscoll and Assoc., 1981

City	Runoff Volume, In/Event		Time Between Storms, Days		Events Per Year*
	Mean	Cost of Variation	Mean	Cost of Variation	
Boston, MA	0.11	1.67	2.81	1.06	130
Atlanta, GA	0.17	1.37	3.75	0.93	97
Davenport, IA	0.13	1.37	4.08	1.01	89
Oakland, CA	0.06	1.62	3.98	1.60	92
Average	0.12	1.51	3.66	1.15	100

* Events per year equals 365 days divided by mean time between storms.

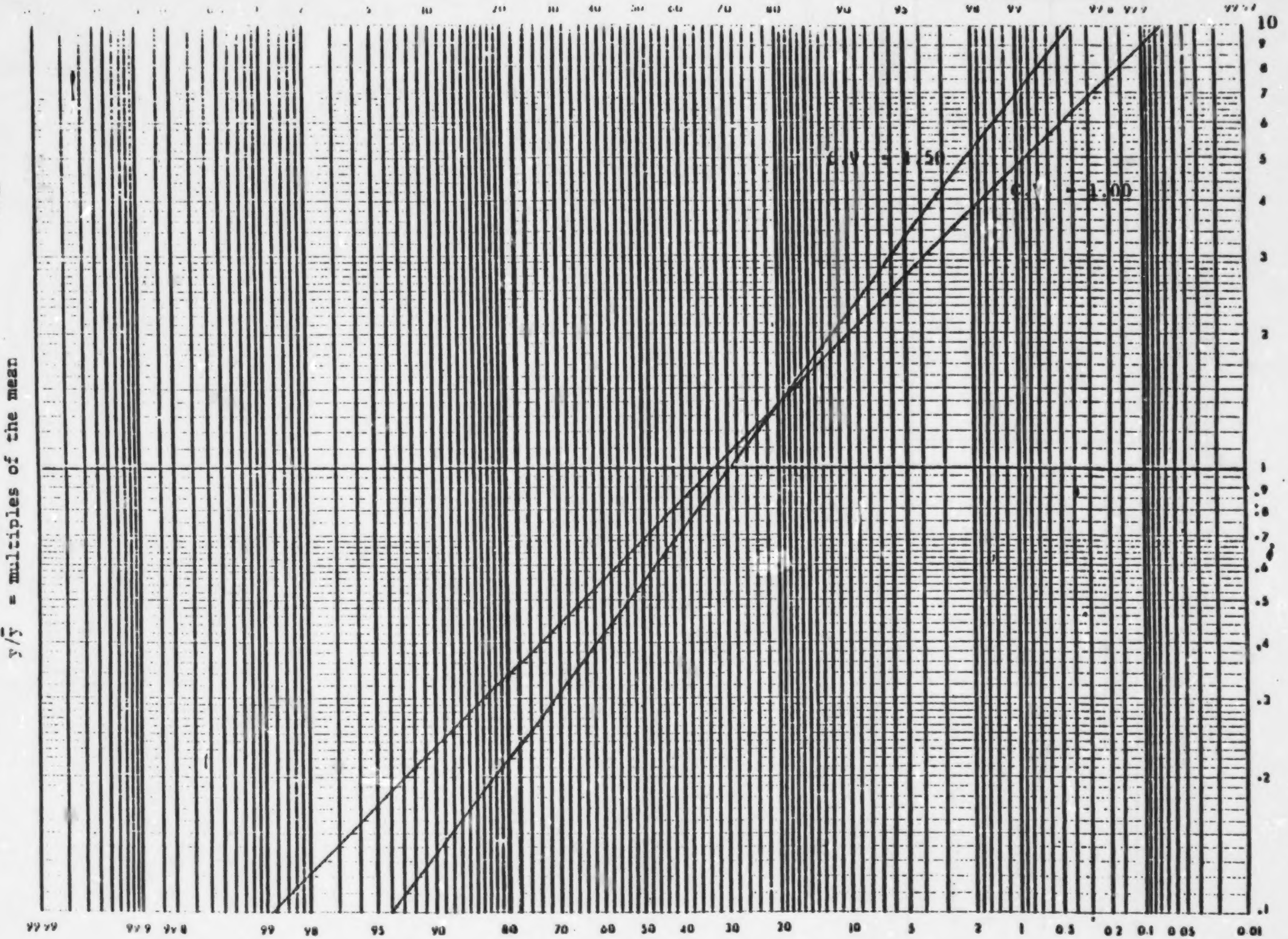


Figure 1. Graphical Solution of Log-Normal Distribution for Coefficient of Variation = 1.0 and 1.5.

TABLE 2. Expected Time Between Rainfall Events for Four U.S. Cities Based on 25 years of Hourly Rainfall Data. Data from Driscoll and Assoc.,1981.

INTERVAL, DAYS	NUMBER OF EVENTS/YEAR				TOTAL	% OF TOTAL	CUMULATIVE % OF TOTAL
	BOSTON, MA	ATLANTA, GA	DAVENPORT, IA	OAKLAND, CA			
0 to 1	27	12	8	22	69	16.8	16.8
1 to 3	64	43	38	33	178	43.4	60.2
3 to 7	30	30	29	24	113	27.6	87.8
7 to 14	8	11	11	8	38	9.2	97.0
14 to 21	1	2	2	3	8	2.0	99.0
> 21	0	0	2	2	4	1.0	100.0
TOTAL	130	98	90	92	410	100.0	100.0

60% of the storm events occur within three days while 97% of the time rains within two weeks. These patterns vary seasonally. The most notable seasonal variation is along the West Coast due to the dry summers. Of course, sweeping is not practical during months when snow and/or freezing weather occurs.

Characteristics of Street Solids

The results of street dirt characterization studies for 27 water quality constituents are shown in Table 3. The nationwide average is the median of the cities for which data are presented. The median is used because of the high variability in some of the data.

Street contaminants comprise only a fraction of the materials washed from urban areas. The balance comes from other impervious and pervious areas, and the atmosphere (Castro Valley, 1979).

Table 4 presents various sources for major pollutant groups in the runoff. The only pollutant group shown to be significantly related to street surface wear and use are heavy metals. Bacteria are thought to originate mainly with animal fecal matter indirectly deposited on the street or on adjacent land. Most of the nutrients are thought to originate from vegetation litter in landscaped areas, undeveloped lands and directly on the street surface. Oxygen demanding materials (BOD and COD) in the runoff are mostly associated with litter and landscaped areas, while sediment sources are mostly thought to be vacant lands and construction sites.

Table 5 summarizes suitable control measures for different types of source areas. As an example, street cleaning can only be utilized on streets and parking lots to control street surface particulates and litter. Street cleaning can therefore not be expected to significantly change the runoff yields of the pollutants that are not significantly associated with the street surface (such as organics and nutrients).

Table 3. Average Chemical Quality of Street Dirt (Pitt, 1981)

Constituent:	"Nationwide" Average*
Volatile Solids	75,000
COD	80,000
BOD_5	10,000
Total P	500
Ortho PO_4	100
Total Kjeldahl N	1,600
Sulfur	1,100
Arsenic	15
Cadmium	3
Chromium	200
Copper	100
Iron	22,000
Lead	1,000
Manganese	500
Mercury	.08
Nickel	20
Strontium	15
Zinc	300
Total Colif. bact.	4×10^5 org/gm
Fecal Colif. bact.	3,000 org/gm
Fecal Strps. bact.	---
Asbestos	175,000 fibers/gm
Bis (2-ethylhexyl phthalade)	25
Dieldrin	0.03
Methoxychlor	1
PCB's	0.7
PCP's	3

* All units are in mg/kg of street dirt, unless otherwise noted.

Table 4. Sources of Contaminants (Pitt ?, 1979)

Common Urban Runoff Pollutants	Street Surface Wear	Automobile Wear and Emissions	Parking Lots	Litter	Vacant Land	Landscaped Areas	Construction Sites
Sediment					X		X
Oxygen Demand				X		X	
Nutrients		X		X	X	X	
Bacteria				X	X		
Heavy Metals	X	X	X				

Table 5. Applicability of Control Measures (Pitt ?, 1979)

Suitable Control Measures	Street Surface Wear	Automobile Wear and Emissions	Parking Lots	Litter	Vacant Land	Landscaped Areas	Construction Sites
Street Cleaning	X	X	X	X			
Leaf Removal			X	X		X	
Repair Streets	X		X				
Control Litter				X	X		
Clean Catch Basins	X	X					X
Control Construction Site Erosion							X

Table 6 presents the Castro Valley study area runoff yields of various parameters for the street surface, non-street urban and undeveloped areas of the watershed. This information was obtained from studies conducted in Castro Valley during the recent 208 study and from the literature. Also shown in Table 6 are the percentages of the source area contributions for each parameter compared to the total runoff loads. Most of the lead is associated with street surface particulates, with very little lead originating from non-street urban and undeveloped areas of the watershed. Most of the total solids yields for the study area are associated with the undeveloped area. Non-street surface developed areas are thought to contribute most of the oxygen demand, nutrient and bacteria yields.

Effect of Rain on Street Loads

Precipitation has two effects on street loads:

1) washoff of some or all of the material on the streets; and

2) buildup of residual material on the streets after the storm due erosion and other sources.

Erosion occurs as a result of relatively large storm events. Smaller storms would be expected to flush the atmosphere, and the directly connected impervious areas. Thus, we would like to know the size of storm events which cause street washoff without significant erosion.

Pitt (1981) has developed a summary table relating runoff volume to the ratio of initial street load to the load removal by the storm event. The results are shown in Table 7.

For example, the ratio for arsenic is 0.16 for a runoff volume of 1.3 inches. The arsenic leaving the area comes from the street and elsewhere, e.g., atmosphere, rooftops, lawns. The ratio of 0.16 indicates that the initial load on the street was 1/6 of the total load leaving the area. It is

Table 6. Castro Valley Creek Runoff Yields (Pitt ?, 1979)

Parameter	Street Surface[1]		Non-Street[2] Urban		Undeveloped[3]		Total
	Tons/Yr	%[4]	Tons/Yr	%	Tons/Yr	%	Tons/Yr
Total Solids	160	33	10	2	320	65	490
Sus. Solids	80	32	60	27	95	41	235
COD	2.1	2	69	72	25	26	96
BOD_5	1.1	7	12	76	2.5	17	16
Total N	0.1	2	2.4	51	2.2	47	4.7
OPO_4	0.013	9	0.12	84	0.01	7	0.14
Pb	1.0	100	0	0	0	0	1.0
Zn	0.072	24	0.23	76	0	0	0.3
Total Colif.(org)	8×10^{10}	<< 1	6×10^{14}	100	?	?	6×10^{14}
Fecal Colif.(org)	8×10^{9}	<< 1	3×10^{14}	100	?	?	3×10^{14}

[1] From Alameda County measurements in Castro Valley during 208 Study

[2] Alameda County 208 SWMM calculations minus street loadings

[3] Data from "the literature" (estimates)

[4] Percentage contribution of source related to total annual runoff yield

Table 7 . Street Loading Sensitivity to Runoff Yield (Pitt , 1981)

Runoff Volume (in)	Total Solids	COD	Total P	Ortho PO_4	Total Kjeldahl N	Arsenic	Copper	Lead	Zinc
4.3	0.080	0.020	0.020	<0.001	0.020	0.044	<0.06	0.10	0.020
3.3	0.085	0.024	0.024	0.001	0.020	0.054	<0.06	0.12	0.025
2.0	0.13	0.054	0.044	0.0017	0.034	0.095	0.06	0.20	0.044
1.3	0.22	0.095	0.080	0.0026	0.045	0.16	0.09	0.35	0.062
0.66	0.50	0.20	0.20	0.0080	0.075	0.50	0.16	0.90	0.13
0.33	1.2	0.45	0.50	0.020	0.20	2.0	1	2.0	0.36
0.13	15	3	3	0.2	2	15	10	20	3
0.05	50	10	10	1	10	50	25	50	10
0.01	500	100	100	10	100	500	250	500	100

67

impossible to tell from this table alone the exact origin of the material or what portion came off the street. For example, arsenic in the atmosphere would wash out with the arsenic in the street. Arsenic in the soil would probably wash out later. However, in order to obtain a rough estimate of the type of storms that flush the streets, assume that some or all of the street contamination is removed first then, the remaining removals are assumed to come from other sources. Thus, for arsenic, a ratio of 2.0 means that 50% of the arsenic in the street was removed while none of the other sources of arsenic left the study area. Figure 2 shows the percent washoff vs. runoff rate for the eight constituents shown in Table 7. It is evident from Figure 2 that the primary area of interest is runoff volumes from 0.1 to 0.4 inches. Lighter storms (< 0.1 in.) do not cause much street washoff whereas larger storms (> 0.4 in.) contribute much more contaminants from sources other than street runoff.

Given that the main area of interest is runoff values ranging from 0.1 to 0.4 inches, the results of Table 7 and Figure 2 can be used to estimate the percent of storm events falling in this range. The lower bound of 0.1 in. of runoff corresponds to the 50% level whereas the 0.4 in. values corresponds to the 90 to 95% level (from Figure 1). Thus, the main area of interest is in the larger storm events up to the 90 to 95% level. Alternatively, only about one half of the storm events flush the streets clean. Thus, the approximate time between these rainfall events is about one week, twice the average time between storms.

Street Pollutant Build-up Rates

Pitt (1981) has summarized the results of work to date on the rate of accumulation of street solids based on five catchments in California and one in Belleview, Washington--all west coast stations for which it is possible to obtain information on long-term accumulation due to the dry summers. The

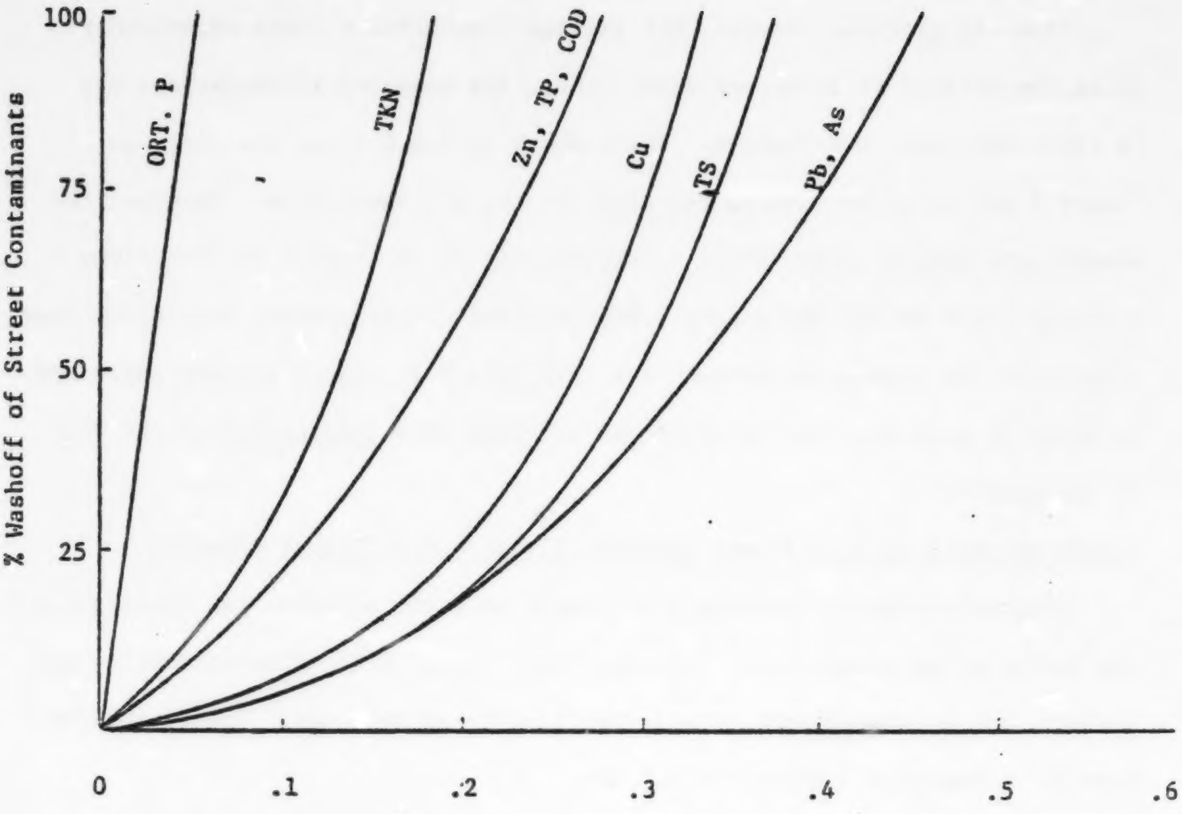


Figure 2 . Washoff of Street Contaminants for Residential Areas in Western U.S. (Pitt, 1981) national estimates, shown in Table 8, are based on calculated values using the curve of best fit for the original data. These national estimates are plotted in Figure 3. All of the data plot as straight lines with positive intercepts representing a base loading and constant growth rates (lb/curb mile/day) of 38.7 (industrial), 20.0 (residential), and 15.0 (commercial).

From the previous section, the average time between storm events that flush the streets is about one week. Thus, the expected accumulations can be taken directly from Table 8. The numbers in Table 8 and the lines in Figure 3 are based on fitting functions to the available data. However, the actual data exhibit quite a bit of variability as is evident in the street loadings reported for the Surrey Downs catchment in Belleview, Washington (see Figure 4). No trends are evident for this data set. About all one could say is that the expected load is about 366 lbs/curb mile independent of the days of accumulation.

Street Sweeping Effectiveness: Single Site With and Without Cleaning

Figure 5 shows performance data (based on a two-day sweeping interval) for the Surrey Downs study area. Two lines are drawn: a 45° line indicating zero removal, and a regression line relating load in to load out. The regression line for a sweeping interval of 2.0 days, is

$$L_F = 180 + 0.45 L_I \tag{1}$$

where L_F = residual load (after sweeping), lbs/curb mile, and

L_I = inital load, lbs/curb mile.

The intersection of these two lines is the graphical solution to the problem of finding the minimum inital load for which sweeping has a positive effect. It is counterproductive to sweep where the streets are cleaner than this minimum initial load since the solids generation form street abrasion exceeds the removal by the sweepers. Thus, the origin of the axes can be translated along the 45° line to (327,327) as indicated on the figure. With the transformation, the gross removal efficiency, ε, is

$$\varepsilon = 1 - L_F'/L_I' = 1 - 0.45 = 0.55 \qquad (2)$$

where L_F' = translated value of L_F (i.e., L_F-327), lbs/curb mile, and

L_I' = translated value of L_I (i.e., L_I-327), lbs/curb mile.

The data set shown in Table 9 indicates negative removals for 13 out of the 27 sweepings. The physical reason for negative removals is that the cleaning process itself erodes the street surface especially when the streets are relatively clean as they would be in this case with only a two-day interval between sweeping events. Thus, the overall net efficiency, ε_N, for a two-day interval is

$$\varepsilon_N = 1 - \bar{L}_F/\bar{L}_I = 1 - 24.7/376.1 = 6.6\% \qquad (3)$$

where $\bar{L}_F$ = mean residual load, lbs/curb mile,

$\bar{L}_I$ = mean initial load, and lbs/curb mile.

Higher efficiencies can be acheived by not sweeping when the initial loads are relatively light. If the general regression equation is

$$L_F = a + bL_I \qquad (4)$$

then sweeping should begin when $L_F = L_I$. Combining these two equations yields

$$(L_I)_{min} = a + b(L_I)_{min} \qquad (5)$$

or

$$(L_I)_{min} = \frac{a}{1 - b} \qquad (6)$$

For Surrey Downs, $a = 180$, $b = 0.45$. Thus, $(L_I)_{min}$ = 327 lbs/curb mile. However, this information is not very useful since the operator of the sweeper has no simple way of measuring L_I. Thus, the appropriate estimate of overall efficiency is ε_N. For this example, the data indicated that sweeping every other day is relatively nonproductive.

Pitt (1981) has summarized the regression relationships for four types of parking conditions and three types of street surfaces. The results are shown in Table 10. In all cases, a simple linear relationship exists between the

Table 8. Total Solids Accumulation on U.S. Streets (Pitt, 1981)

DAYS OF ACCUMULATION	TOTAL SOLIDS, lb./curb mile		
	RESIDENTIAL	INDUSTRIAL	COMMERCIAL
0	400	670	300
1	420	710	315
2	440	750	330
3	470	790	345
4	490	830	360
5	510	870	375
7	530	940	405
10	600	1050	450
15	700	1250	525

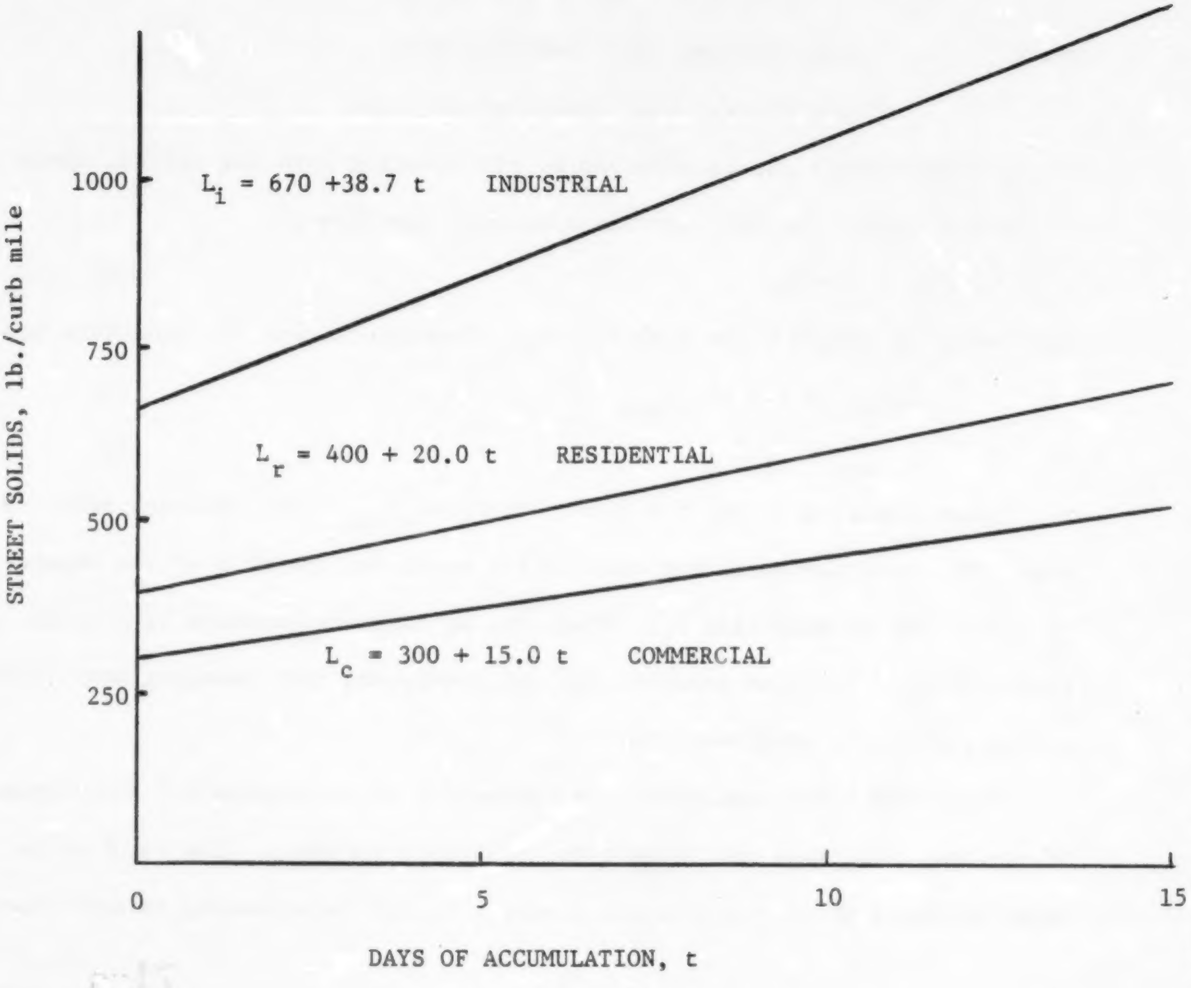


Figure 3. Street Loading vs. Days of Accumulation (Pitt, 1981)

Table 9. Solids Removal Efficiencies of Street Sweepers, Surrey Downs and Lake Hills - Twenty-Seven Sweepings

N	Surrey Downs Loadings (lb/curb mile)			Lake Hills Loadings (lb/curb mile)		
	Before, L_I	After, L_F	Difference	Before, L_I	After, L_F	Difference
1	529	496	33	380	330	50
2	538	545	-7	238	240	-2
3	695	442	253	295	267	28
4	713	412	301	292	270	22
5	326	265	61	265	311	-46
6	303	317	-14	228	239	-11
7	295	386	-91	229	200	29
8	371	323	48	244	250	-6
9	424	332	92	216	214	2
10	333	353	-20	124	148	-24
11	406	315	91	182	199	-17
12	472	423	49	198	211	-13
13	437	427	10	250	235	15
14	384	444	-60	167	123	44
15	290	304	-14	150	148	2
16	305	375	-70	161	147	14
17	235	252	-17	110	112	-2
18	237	245	-8	108	121	-13
19	281	295	-14	159	145	14
20	336	352	-16	261	210	51
21	352	320	32	144	179	-35
22	251	249	2	270	197	73
23	328	315	13	242	214	28
24	302	306	-4	194	191	3
25	363	364	-1	109	310	-201
26	296	285	11	185	300	-115
27	353	345	8	190	215	-25
Σ	10,155	9,487	688	5,591	5,726	-135
Mean	376.1	351.4	24.7	207.1	212.1	-5.0

Table 10. Estimated Street Cleaner Productivity (Pitt, 1981)

Parking Conditions	Smooth Asphalt				Rough Asphalt				Oil and Screens (Semi-Improved)			
	Range for L_I	Equation	$(L_I)^*_{min}$	Removal Efficiency at $(L_I)^\Delta_{max}$	Range for L_I	Equation	$(L_I)^*_{min}$	Removal Efficiency at $(L_I)^\Delta_{max}$	Range for L_I	Equation	$(L_I)^*_{min}$	Removal Efficiency at $(L_I)^\Delta_{max}$
Light	100-250	$L_F = 150 + 0.36\ L_I$	234	0.04	500-620	$L_F = 520 + 0.20\ L_I$	650	<0	1000-1500	$L_F = 340 + 0.74\ L_I$	1310	0.03
Moderate	100-230	$L_F = 110 + 0.54\ L_I$	239	<0	500-650	$L_F = 360 + 0.44\ L_I$	643	0.01	1000-1430	$L_F = 220 + 0.83\ L_I$	1290	0.02
Extensive Short Term	-	-	-	-	500-670	$L_F = 290 + 0.55\ L_I$	644	0.02	1000-1600	$L_F = 200 + 0.85\ L_I$	1330	0.03
Extensive Long Term	100-230	$L_F = 55 + 0.75\ L_I$	220	0.01	-	-	-	-	1000-1600	$L_F = 200 + 0.85\ L_I$	1330	0.03

* $(L_I)_{min} = a/(1-b)$ from equation $L_F = a + bL_I$

Δ Efficiency = $1-(a+b(L_I)_{max})/(L_I)_{max}$

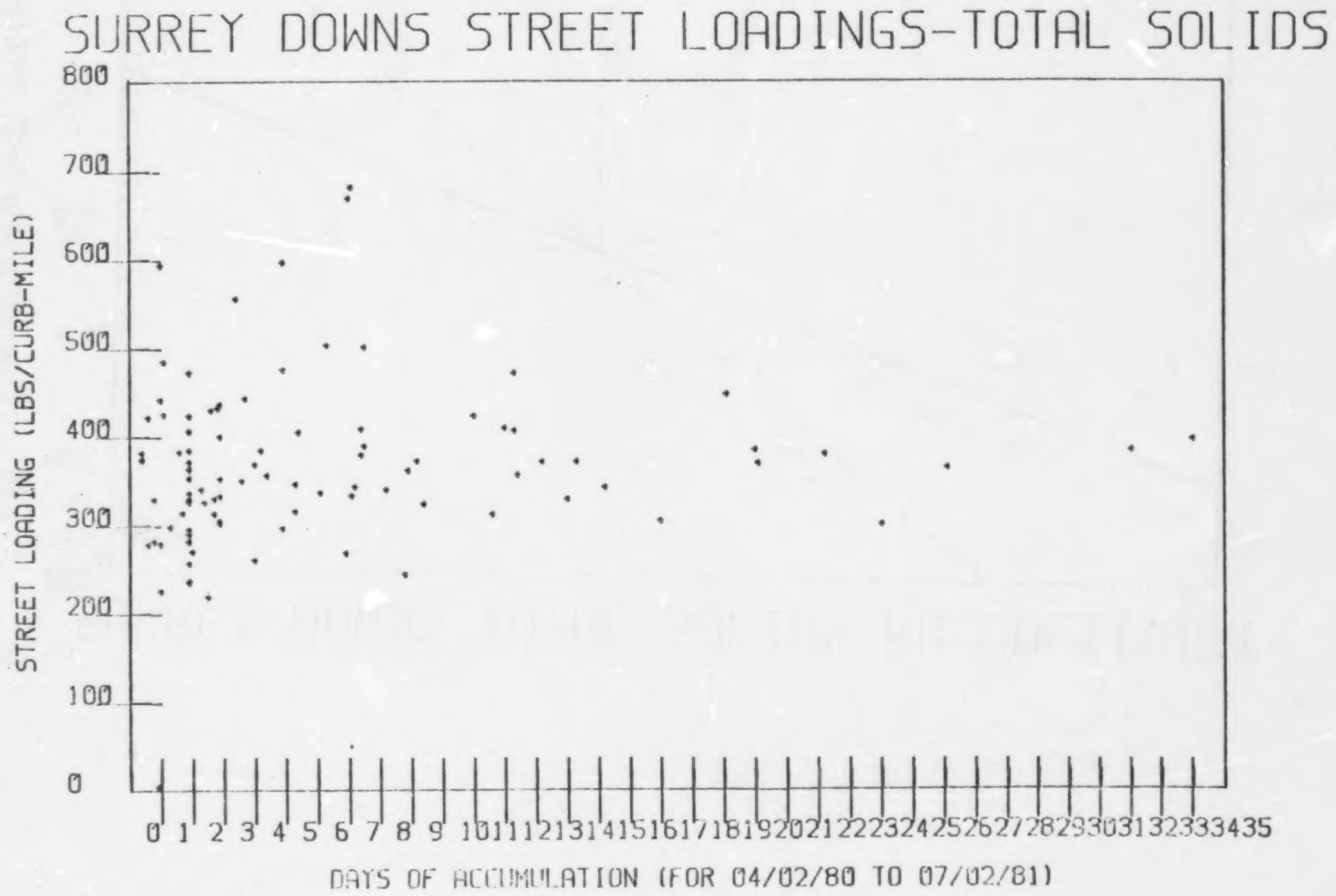


Figure 4. Surry Downs Street Loadings - Total Solids (Pitt, 1981)

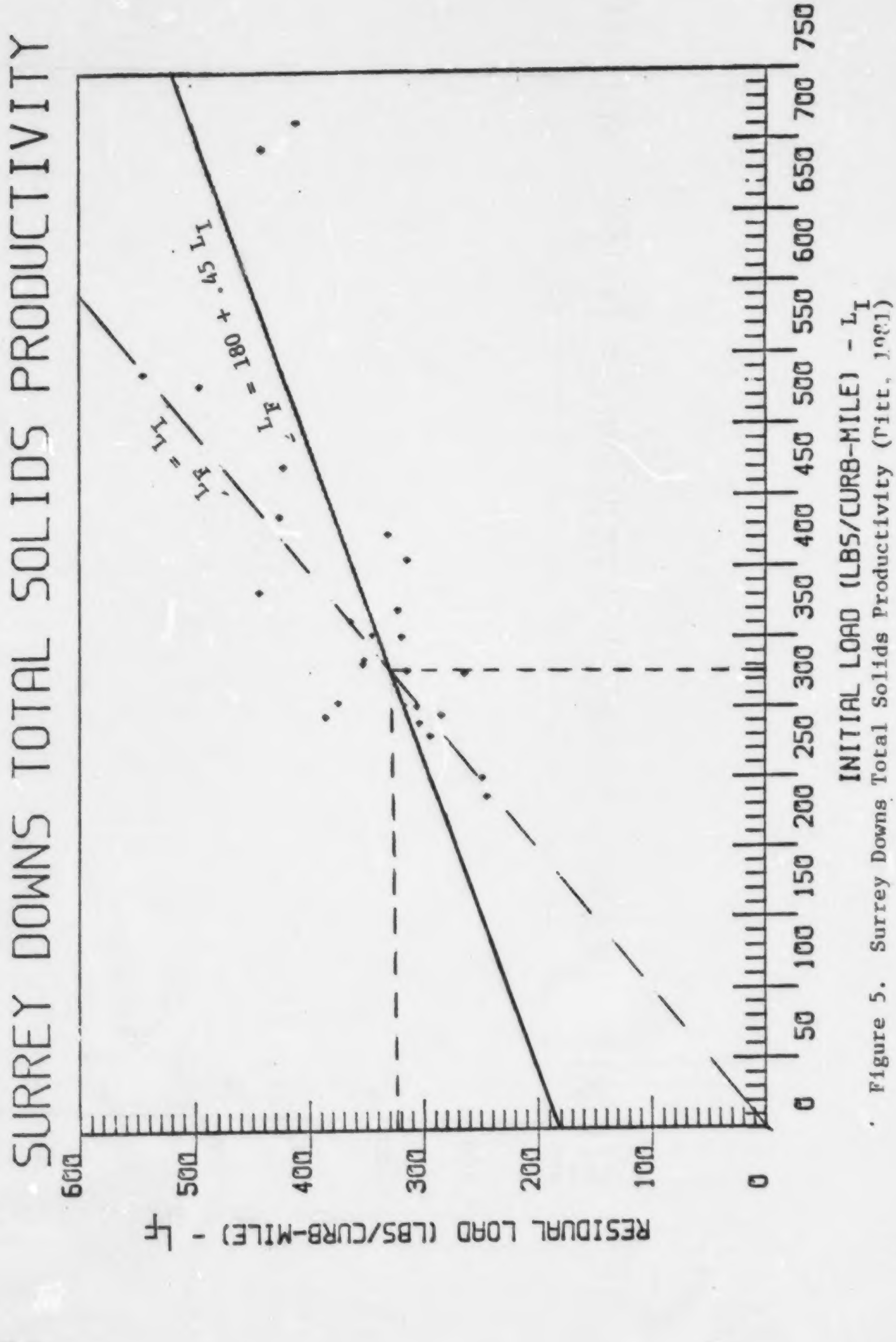


Figure 5. Surrey Downs Total Solids Productivity (Pitt, 1981)

initial and final loads. The user only needs to know the mean initial load, $\bar{L}_I$, to estimate overall net efficiency, i.e.,

$$\varepsilon_N = 1 - \bar{L}_F/\bar{L}_I = 1 - (a + b\bar{L}_I)/\bar{L}_I \qquad (7)$$

For example, the regression equation for rough asphalt with moderate parking conditions is

$$L_F = 360 + 0.44\ L_I \qquad (8)$$

Assume $\bar{L}_I = 600$. Using equation (6), efficiency is

$$\varepsilon_N = 1 - \frac{360 + 0.44\ (600)}{600} = -\ 0.04,$$

a negative number. If $L_I = 650$, the upper limit on the range of L_I, then $\varepsilon_N = 0.01$. Using equation (6), the minimum L_I to obtain a non-negative efficiency is

$$(L_I)_{min} = \frac{360}{1 - 0.44} = 643 \text{ lb/curb mile}$$

Consequently, it would be unwise to sweep in this case. Table 10 shows $(L_I)_{min}$ for those ten equations. In two of the ten cases efficiencies are negative for the entire range of L_I. The maximum attainable efficiency in the specified range of L_I is only 4%. Thus, these results indicated very poor performance for street sweepers.

Effectiveness of Street Sweeping Programs

If the street accumulation data do not show a trend over a time, (e.g., the Surrey Downs data in Figure 4) then the effectiveness of the street sweeping program can be evaluated simply by determining the average street loading with and without a street cleaning program. The Surrey Downs data are summarized in Table 11.

Table 11. Results of Surrey Downs Sweeping Studies (Pitt, 1981)

Condition	Average Street Loads, Lb/curb mile	% Reduction
No sweeping	366	--
Sweep 3 times/week	333	9.0
Immediately after sweeping	330	9.8

These results indicate that frequent sweeping reduces total solids only by 9 or 10 percent. Thus, if 70% of a heavy metal such as lead originates in the street, then the expected impact of sweeping three times per week is only (9%) (.7) = 6.3% reduction in the total (street and non-street) lead load.

The effectiveness of street sweeping can be estimated by selecting two similar areas, sweep one of these areas, and compare the loads leaving the two areas. Results of this procedure as applied to Surrey Downs and Lake Hills are described below.

Figures 6 and 7 are plots of storm runoff yields for both basins for total solids and lead. Most of the available data are only for the period when Lake Hills was cleaned and Surrey Downs was not cleaned. Therefore, basin calibrations are not available, even though the basins were selected with similarities in mind. These examples, along with the above discussion of the effects of street cleaning on street dirt loads, demonstrate how poor this method of analysis is. The first problem is selecting the appropriate runoff data for comparisons. Bellevue has more available data than any other NURP project: 116 storms. Only about 50 of these 116 storms include complete monitoring simultaneously from both the control and test basins. If STORET data are used, then there is no way of knowing which storms were completely monitored, and which storms need to be combined. Another serious problem is the differences in rainfall observed at both sites during the same storms. Correlations in rain quantities were made between the Lake Hills and Surrey Downs sites to a relatively high degree of significance, but individual rains did vary substantially. Therefore, of the 50 complete monitoring sets, only 26 storms resulted in total rain quantities within 25% of each other. Previous correlations showed a very "strong" relationship between rain quantity and runoff pollutant yield (almost 1 to 1 for rain quantities up to 0.5 inch).

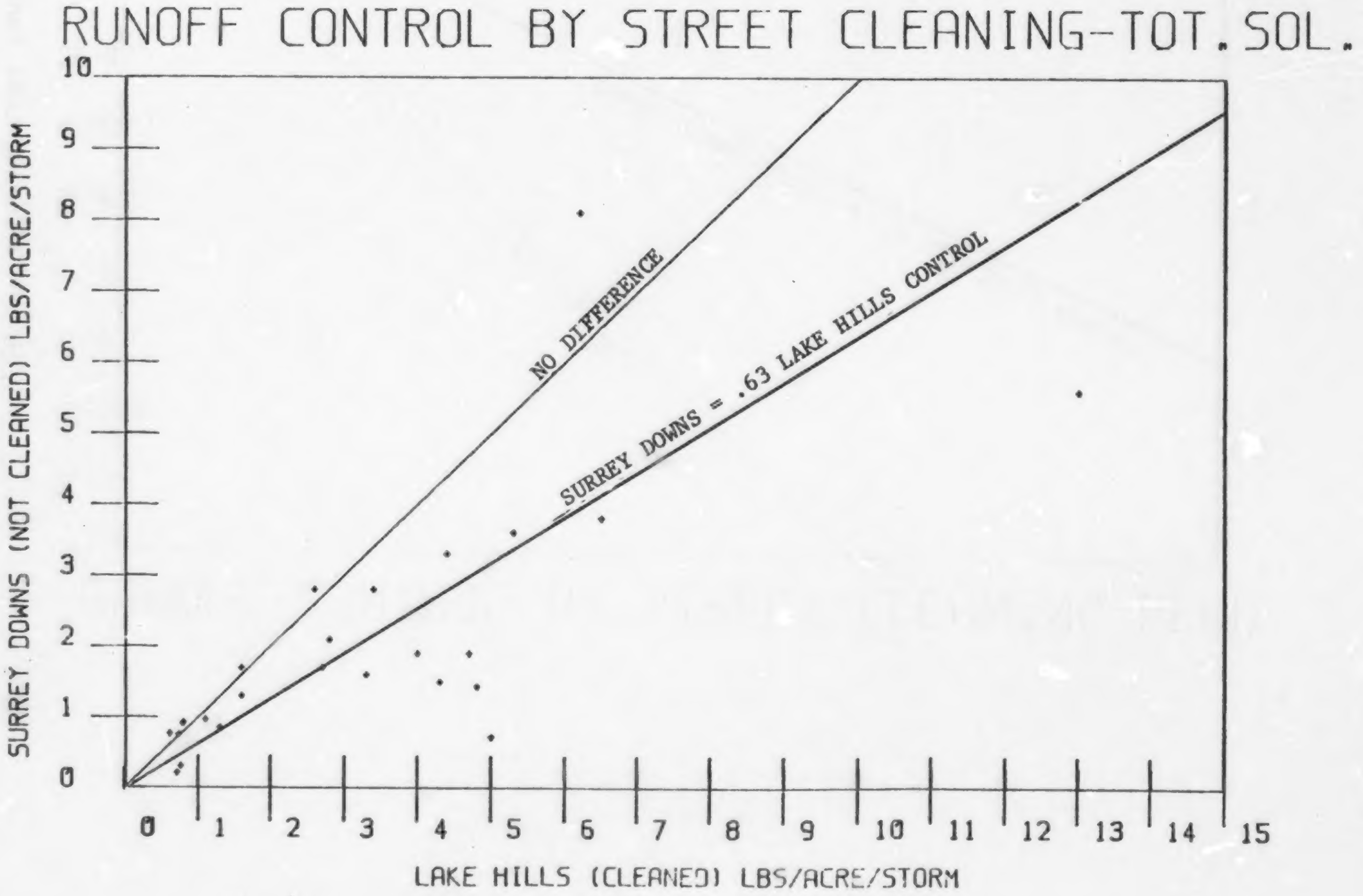


Figure 6. Runoff Control By Street Cleaning-Total Solids (Pitt, 1981)

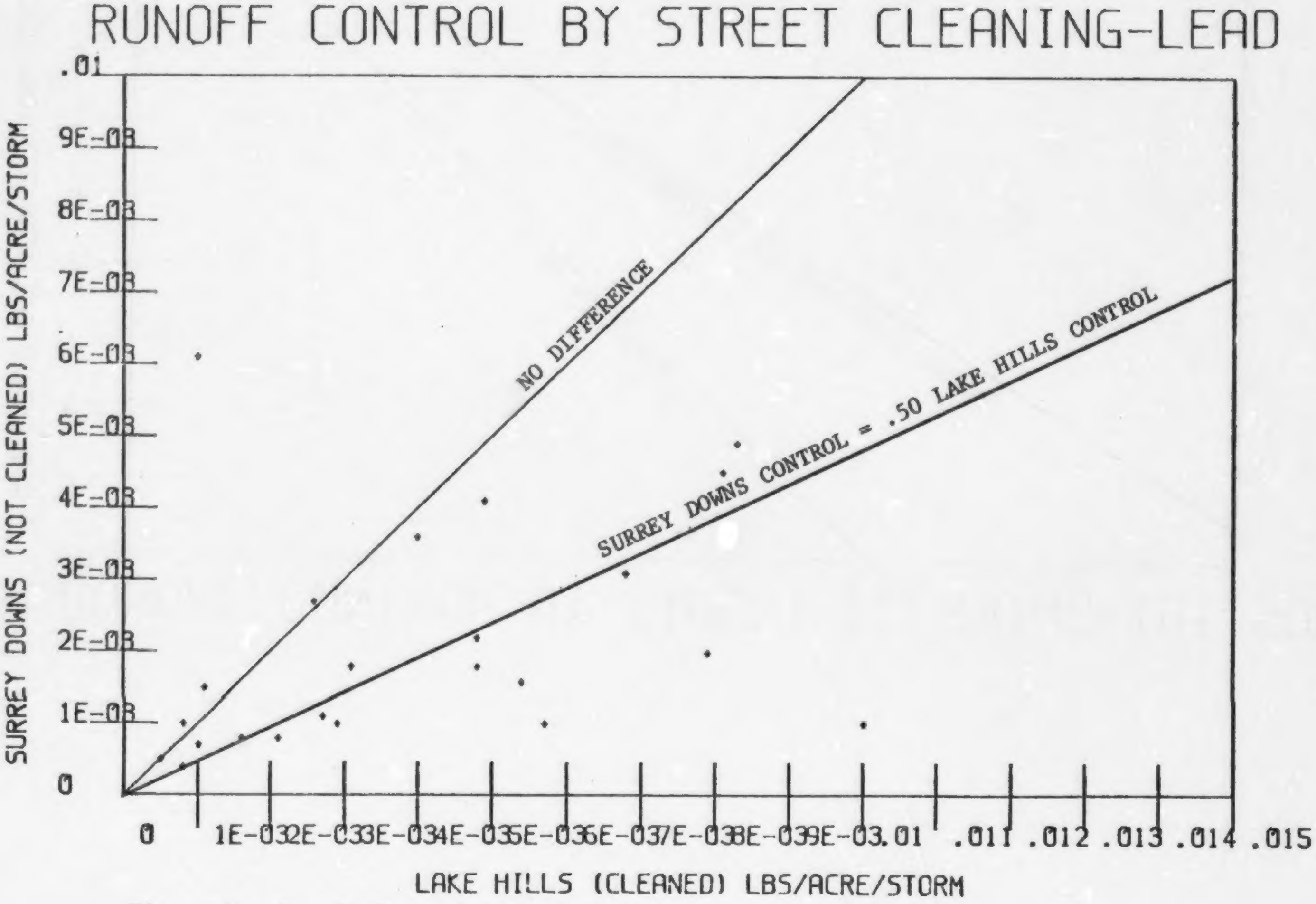


Figure 7. Runoff Control by Street Cleaning-Lead (Pitt, 1981)

Therefore, a 25% difference in total rain at the two sites can be expected to produce nearly a 25% difference in runoff pollutant yield. As noted above, extensive street cleaning compared to no street cleaning reduces street loads by less than 10%, and the resultant runoff yields for most pollutants could be expected to be much less. Therefore, even with "perfect" basin calibrations, the noise in the system due to rain differences can be easily greater than twice the expected difference due to street cleaning. If rains within, say 10%, were selected, only a very few events would be available for study. Belleview probably has more consistent rains over the city than many other NURP cities. Fortunately, the "information component" (street cleaning effects) is expected to be greater in the other NURP cities.

Regression lines in Figures 6 and 7 show that the Surrey Downs catchment (the "control") produces lower total solids and lead loads than the "cleaned" Lake Hills basin. In fact, only 25% of the storms had smaller unit area yields in the "cleaned" basin when compared to the "control" basin. Again, the basins have not yet been "calibrated". The ongoing sampling scheme will allow these direct comparisons to be made, along with basin calibrations, but other data will also be collected allowing alternative analytical methodologies. This direct comparison appears to be the simplest procedure, but without intimate knowledge of the data set (for completeness and compactability) and without adequate calibration periods, it can be extremely misleading. Thus, the analysis of the sensitivity of street loads to runoff yields and simple productivity relationships to identify the cleaning effort needed to obtain specific street loads should be the primary methodology. Comparisons between control and test basins should also be made, but only after careful review of the data.

Cost-Effectiveness of Street Sweeping Programs

Unit costs for sweeping streets in Alameda County, California were found to be $15.00/curb mile (Pitt, 1981). Heaney et al. (1977) used a value of $7.00/curb mile based on 1976 survey data of the American Public Works Association. For this inital assessment of control effectiveness a unit cost of $12.00 per curb mile is assumed.

Heaney and Nix (1977) developed a procedure for evaluating the relative cost effectiveness of street sweepers as compared to detention basins and other controls. The performance of the system was simulated using a simple model which assumes:

a) zero base load and a constant buildup rate per day,

b) an exponential washoff relationship based on the assumption that one-half inch of runoff per hour removes 90% of the remaining street contaminants.,

c) a constant percent of the load is available to be swept,

d) rainfall does not act as a source of contaminants, and

e) removal efficiencies are independent of loadings.

Information presented earlier in this section indicates that several of these assumptions are untenable. A given level of control applied over several months results in a known average loading on the street. Insufficient data exist to support the assumptions of a positive linear or nonlinear accumulation of solids with time. Unfortunately, it is very expensive and time consuming to sweep for several months or a year at a fixed interval to obtain a single estimate of removal efficiency. The type of curve we hope to get looks like Figure 8. However in this case, each data point is based on several months of sampled data. Figure 8 shows additional removals as street sweeping intensifies. However, we are limited by two primary factors: only a portion of the total load is sweepable; and relatively intensive sweeping generates added loads through street abrasion.

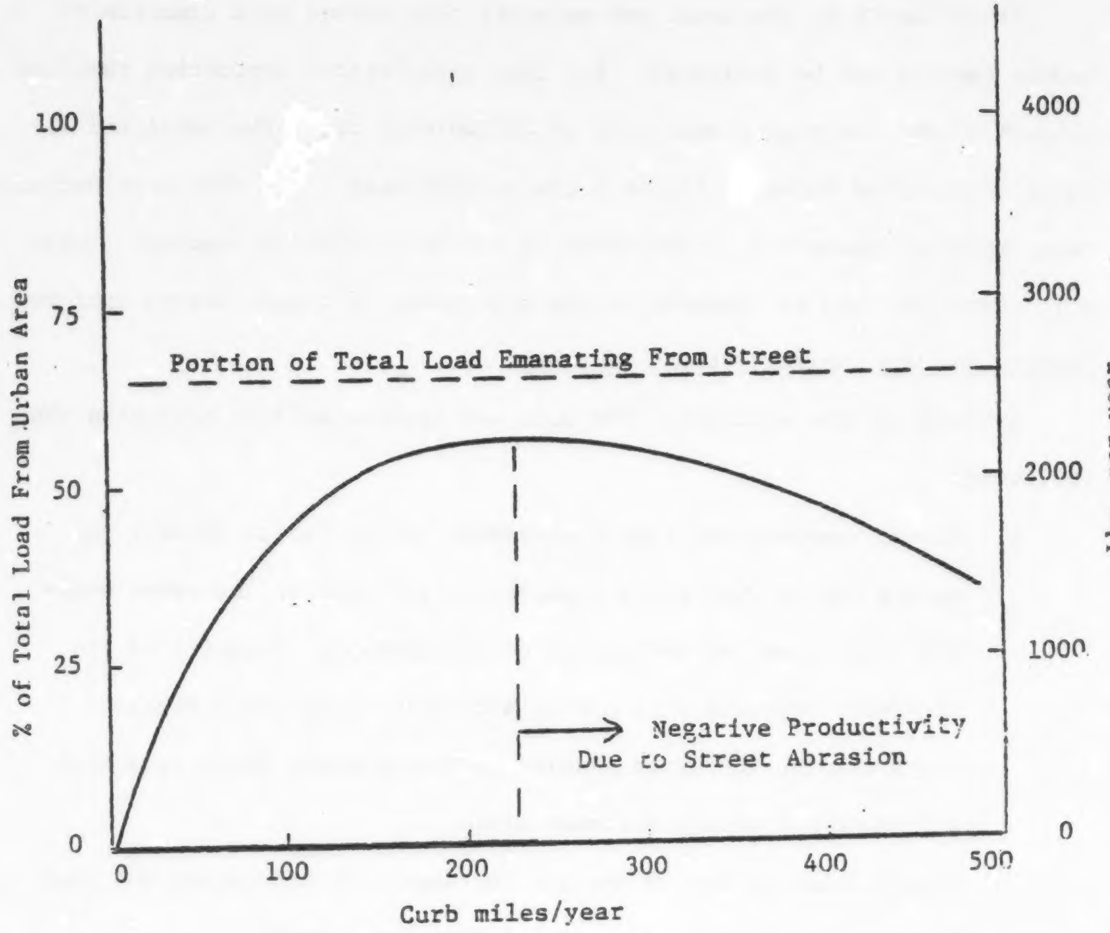


Figure 8. Hypothetical Production Function for Street Sweeping

Given Figure 8, the total and marginal cost curves as a function of pounds removed can be developed. For this hypothetical production function (Figure 8) and assuming a unit cost of $12.00/curb mile, the total and marginal cost curves shown in Figure 9 can be developed. For this hypothetical case, marginal costs are in the range of $ 0.50 to 3.00/lb removed. These unit costs can then be compared to the unit costs of other control options.

Summary and Conclusions--Street Sweepers

Analysis of the available NURP data and earlier studies indicates the following:

1) Street sweepers can remove suspended solids (up to 30-40%) and metals (up to 90%) since significant portions of the urban washoff from these two categories of contaminants originate on the streets. Sweeping will not be effective in removing organic contaminants, nutrients, and/or coliforms since these constituents wash off from non-street areas.
2) Street loadings may or may not increase with time since the last storm. Limited NURP data do not show any trends.
3) Streets are washed by runoff events in the range from 0.1 inch to 0.4 inch. This range of events accounts for about 40% of the total events per year. About 50% of the events do not cause significant washoff (< 0.1 in) while 10% of the events are large enough (> 0.4 in) such that non-street loads dominate.
4) The expected time between runoff events which wash the streets is about one week.
5) The expected total solids load after a week in lbs/curb mile is 530 (residential), 940 (industrial), and 405 (commercial).
6) The reported removal efficiencies for single or paired basins are quite low, i.e., < 10%. If available data are a representative

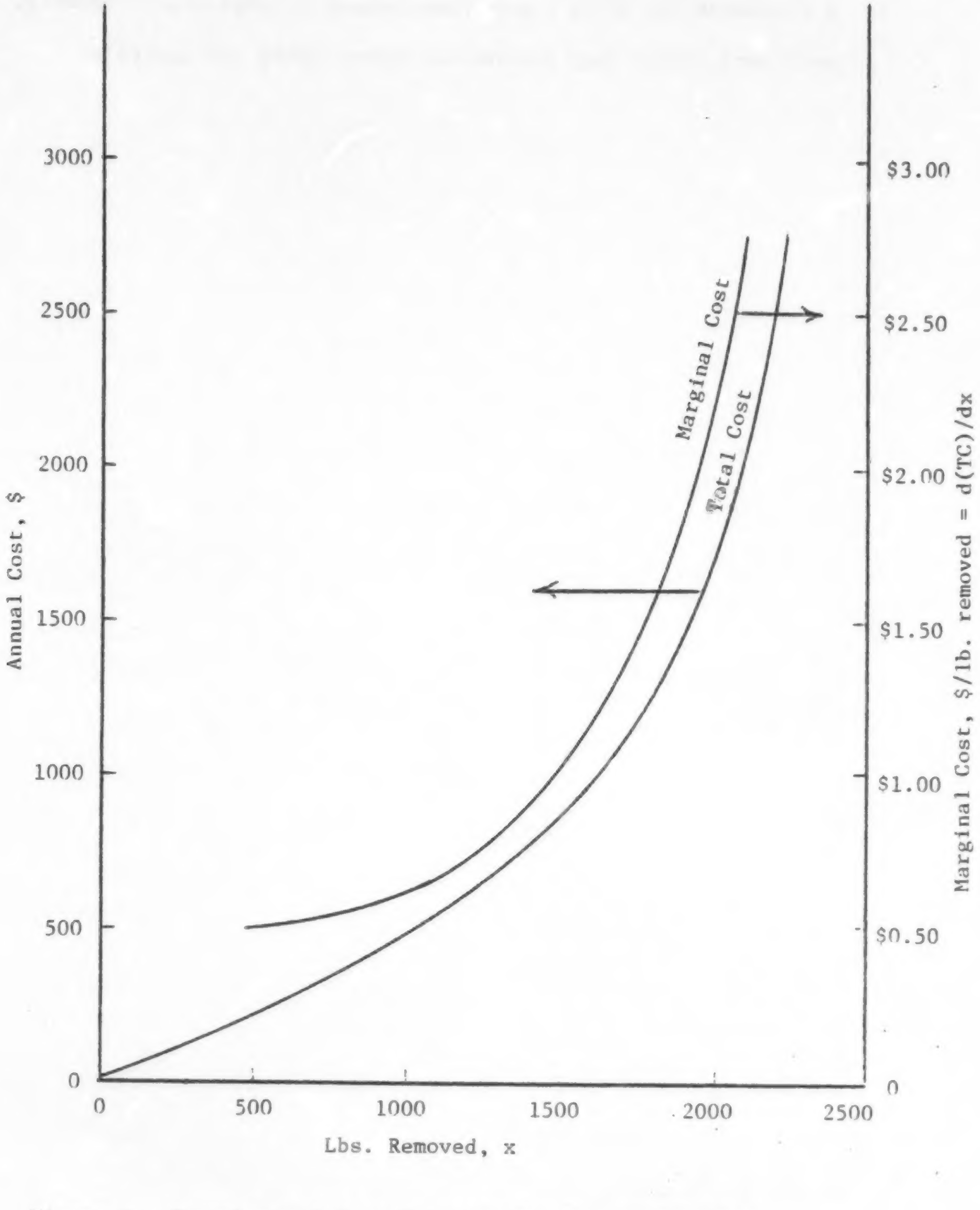


Figure 9. Hypothetical Cost Function for Street Sweeping

range, then street sweeping does not appear to be a very cost effective control option.

7) A procedure for doing cost-effectiveness is available. However, more performance data are needed before doing the analysis.

References

1. Castro Valley First Year Work Plan, 1979.

2. Driscoll, E.D. and Assoc., "Combined Sewer Overflow Analysis Handbook for Use in 201 Facility Planning, Volume II: Appendices". Draft Report to USEPA, July 1981.

3. Heaney, J.P. et al., "Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges, Volume II: Cost Assessment and Impacts", EPA-600/2-77-064, Cincinnati, OH, 1977.

4. Heaney, J.P. and S.J. Nix, "Storm Water Management Model Level I--Comparative Evaluation of Storage-Treatment and Other Management Practices", EPA-600/2-77-083, Cincinnati, OH, 1977.

5. Pitt, R., Unpublished Data, 1981.

WATER QUALITY IMPROVEMENTS BY STORMWATER DETENTION

Introduction

Detention is widely used in sanitary sewage treatment plants and is particularly important in the field of stormwater flow and pollution control[19,20]. This section describes the role of urban stormwater detention facilities in water quality management, and the various methods to evaluate the pollutant control performance of the facility. Most of the material is taken directly from a synopsis of evaluation methods by Nix et al[23].

A detention facility retains stormwater and attenuates peak discharges. In addition to these roles, detention provides some measure of stormwater quality improvement. However, because of the variable nature of stormwater flows and pollutant loads, the mechanisms governing the performance of detention facilities as pollution control devices are not well understood. The picture is further clouded by the lack of useful performance data. The poor condition of the data base is attributable to the expense and time involved in collecting any type of stormwater data.

At present, most detention basins are sized using a design storm[20]. This concept has served well for many decades in the design of flow control structures. However, design storms are difficult, if not impossible, to determine for stormwater pollution control. This difficulty is directly related to the lack of historical data, the inability to measure benefits, the unreliability of pollutant measurements, and the unclear relationship between stormwater flows and pollutant loads. A design storm must also be accompanied by design "conditions" for the receiving water (and the additional uncertainties and data requirements). In general, the design storm is not very useful when investigating pollution control capabilities.

An alternative approach, advocated here, is to analyze the long-term average or, in more detailed studies, a time series response. Average performance is a useful preliminary indicator of a detention basin's contribution to the abatement of total pollutant loads and to provide initial design estimates. The analysis of a time series of facility performance parameters (e.g., suspended solids removal) provides useful information lacking from a preliminary analysis; namely, the abatement of extreme events (e.g., standards violations). This information is vital if the primary function of detention is to prevent "catastrophic" events. Unfortunately, such a time series analysis requires an extensive pilot plant study and/or computer simulation. Pilot plant studies are time consuming and expensive. Computer simulation is less expensive in terms of dollars and time but the simulation techniques are invariably open to questions concerning their validity.

Ideally, a problem should be approachable from several levels of sophistication. This philosophy is carried through the rest of the section. The evaluation techniques presented here range from simple hand calculations for estimating average performance to sophisticated computer models for time series analyses (see appendices). Before discussing the performance evaluation methods, a brief overview of the role and theory of detention in stormwater quality management is in order.

Role of Detention in Stormwater Quality Control

Detention is probably the most effective stormwater management tool available to the design engineer[19]. Additionally, several states and localities require detention to manage stormwater flows from new developments. This combination of technical/economic desirability and regulatory pressure necessitates the development of analytical tools to determine the pollution control capability of stormwater detention.

Detention facilities provide flow or flood control by retaining, buffering and attenuating flows. These attributes also provide some level of pollution control by detaining the flow long enough for removal by physical and/or biochemical processes to occur. Detention facilities are often designed to serve the needs of flow control with pollution control as a "side" benefit. This approach seems reasonable because of the more obvious destructive power of uncontrolled stormwater flows. However, there are cases in which detention is provided primarily for pollution control, e.g., Ottawa, Ontario, or to perform both functions, e.g., throughout Florida. In the case of a true dual-purpose facility, the proper mixture of flow and pollution control is a complex economic problem in which the benefits of each function must be evaluated and balanced against each other. This question will remain unanswered here as the emphasis is on the evaluation of pollution control performance and not the level of control desired.

The mechanisms controlling pollutant removal in detention facilities are complex and numerous. Figure 1 summarizes the more significant mechanisms. Most of these factors can be related to the concept of detention time. Simply defined, detention time is the time a parcel of water spends in the basin or pond. More precise definitions are presented in a later discussion. The mechanisms shown in Figure 1 are each affected by or affect detention time. Particle settling is affected by detention time as is biological stabilization. Outlet structures can be designed to achieve various detention times. The inflow rates have a direct bearing on detention times. In short, detention time is the primary

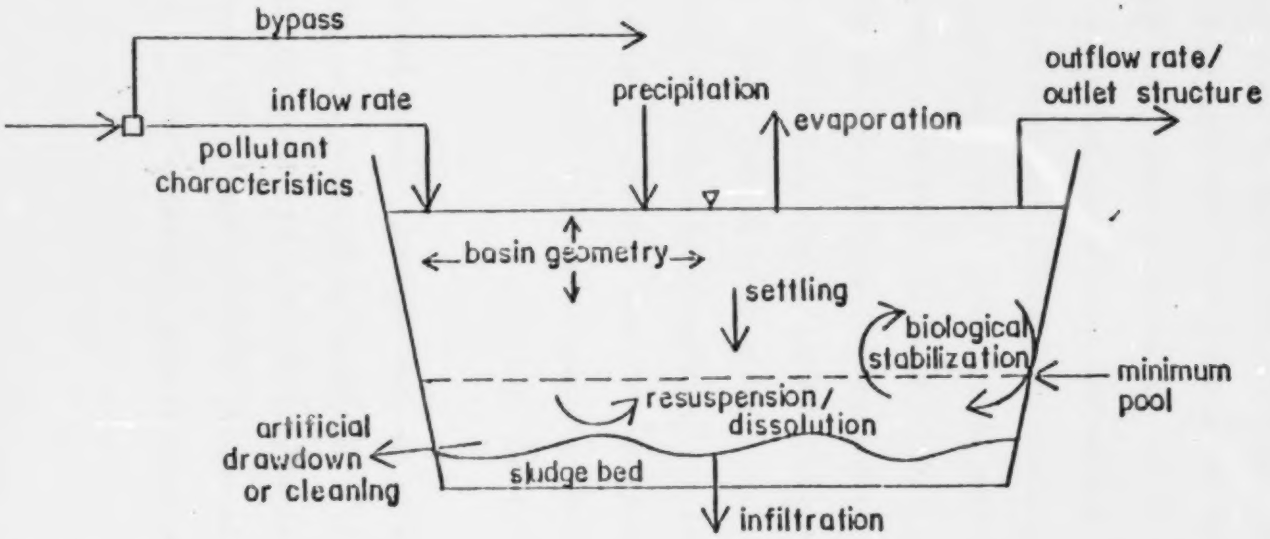


Figure 1. Mechanisms Affecting Pollutant Removal in Detention Facilities (source: ref. 23)

indicator of pollution control capability. However, some problems are encountered in precisely defining detention time in the case of intermittent stormwater flows (see later discussion).

Predicting Stormwater Detention Pond Performance

There are many methods for estimating the pollution control capability of detention basins and ponds. The range of sophistication is wide but necessary to fit the various scenarios that might confront an engineer. Several methods are described in Appendix I.

The primary indicator of pollution used throughout much of this section is total suspended solids (TSS). This constitutent is one of the most commonly and reliably measured stormwater contaminants. Additionally, many of the techniques only address suspended solids. Five-day biochemical oxygen demand (BOD_5) is also a commonly, but much less reliably, measured pollutant and is included where possible. Many other pollutants are measured but, because of the lack of data availability or reliable test procedures, are omitted. However, it may be possible to estimate the effect on other pollutants by relating them to commonly measured constituents (e.g., suspended solids).

Detention Time

Detention time is the most important single determinant of pollutant control potential. The concept of detention time is generally understood, but its computation, especially in stormwater detention, is not always so clear. The basic definition is simple; detention time is the length of time a parcel of water spends in the basin or pond. Detention time is easy to compute under steady state conditions, i.e.,

$$t_d = S/\bar{q} \qquad (1)$$

where t_d = detention time, sec,

S = detention volume, ft^3, and

$\bar{q}$ = constant flow rate, ft^3/sec.

In completely-mixed units, t_d represents the average detention time. In plug-flow units, t_d is the actual time all parcels spend in the detention basin. Unfortunately, a steady state condition is rarely found in a sanitary sewage plant and is certainly improbable in stormwater detention facilities. Therefore, such a computational definition is of limited value. Several analysts have applied this definition to a design storm but this concept was discounted earlier.

For stormwater flows, the theoretically ideal method is to calculate the length of time each parcel of water spends in detention. Obviously, this is not practical in real-world situations. This problem can be circumscribed by recognizing that factors such as outlet structure and basin geometry control detention time and, fortunately, they are much easier to measure or compute. Varying these factors will produce different overall control levels which can be measured directly. However, it may be necessary to compute detention time in a computer simulation model because of its predictive value. These simulators allow the user to vary the factors controlling detention time[8,15,27]. This is often accomplished by modeling the detention basin or pond as a plug-flow reactor. Such a model simply queues relatively small parcels or plugs (ideally, the parcel is infinitely small) through the basin[24]. In other words, the first parcel of water entering the basin is the first parcel to leave. Pollutants entering a basin with a plug are assumed to remain with that plug. The detention time can be calculated for each plug by

$$t_{d_i} = t_{d_i}(2) - t_{d_i}(1) \qquad (2)$$

where t_{d_i} = detention time for plug or parcel i,

$t_{d_i}(1)$ = point in time that plug i entered the basin, and

$t_{d_i}(2)$ = point in time that plug i left the basin.

Detention facilities may also be viewed as completely-mixed or arbitrary-flow reactors[24]. True values of detention time are difficult to calculate under these assumptions. In completely-mixed reactors the inflow parcels and associated pollutants are completely intermixed with all other parcels in the unit and, thus, lose their identity. Arbitrary-flow reactors are a blend of plug-flow and completely-mixed reactors. Most detention units can be thought of as plug flow or arbitrary flow reactors. This is a realistic assumption for stormwater detention facilities experiencing little or no turbulence. Completely-mixed stormwater detention is an anomaly when one considers that a major pollutant removal mechanism is particle settling.

The purpose of this discussion is to provide some insight of the role of detention time in the evaluation of detention basins and to serve as a preface to a cautionary note. It is often tempting to take the volume of a detention basin or pond and divide it by some measure of flow and call it "detention time". This is probably due to the traditional desire to define a detention time. But this is essentially impossible in stormwater detention -- there is no single value of detention time. However, several variables are used in this section that appear to be detention time (i.e., volume/annual flow) but, conceptually, they are not. They are only indicators of the relative detention capability (and, in turn, pollution control capability).

Summary and Conclusions

This section described the water quality aspects of stormwater detention facilities and presented several methods for predicting removal rates (see appendices). Detention time is the primary determinant of pollutant removal efficiency but its use is sometimes misunderstood. Various methods of estimating removal efficiency are presented. Unfortunately, very few field data are available at this time. Thus, it is essential to perform waste characterization and treatability studies on the local urban stormwater, to aid the analysis. These data can be used with the preliminary estimates to guide the use of computer simulation in the evaluation of the continuous operation of the detention facility.

Appendix I: Basin Evaluation Methods

This appendix describes various methods to estimate or evaluate detention basin performance. Examples are presented to illuminate the procedures.

The following information is common to all of the examples presented in the detention basin performance summaries. Data particular to a specific example are given in that example.

A 600-acre (243 ha) drainage basin, located in a primarily residential area near Minneapolis, Minnesota has an average annual precipitation of 26.0 in. (66.0 cm.). The area has the following land use breakdown:

Land Use	Area, acres (ha)	Percent of Total
Residential	420 (170)	70.0
Commercial	30 (12)	5.0
Industrial	--	--
Other (parks, schools, etc.)	150 (61)	25.0
Total	600 (243)	100.0

The precipitation statistics for Minneapolis are given below.

Parameter	Mean	Coefficient of Variation
Duration	D_p = 6.30 hr/event	$\nu_d = 1.14$
Intensity	I_p = 0.047 in/hr (0.119 cm/hr)	$\nu_i = 1.73$
Volume	V_p = 0.25 in/event (0.64 cm/event)	$\nu_r = 1.56$
Intervent time	Δ_p = 84 hr	$\nu_\delta = 1.02$
Events/year	104	--

From these statistics and the methodology developed by Hydroscience, Inc.[17], the mean runoff event intensity, Q_R, is 0.0146 in/hr (0.0371 cm/hr) and the mean runoff event volume, V_R, is 0.081 in (0.206 cm). The coefficients of

96

variation, ν_q and ν_{vR}, are assumed to equal ν_i and ν_v, respectively. The average annual runoff is (0.081 in/event)(104 events) or 8.42 in/yr (21.39 cm/yr).

A rectangular detention pond with a capacity of 10 acre-ft (12335 m^3) is proposed to provide stormwater quality control. The pond's capacity is measured to the bottom of a broad-crested weir (at a depth of 12 ft (3.66 m). The weir is 20 ft (6.10 m) long and rapidly discharges large flows. The total pond depth is 16 ft (4.88 m). The length and width are 300 ft (91.4 m) and 121 ft (36.9 m), respectively. A 6-inch (15.24 cm) orifice is located at 6 ft (1.83 m) for the slow release (over approximately one day) of the volume between 6 ft (1.83 m) and 12 ft (3.66 m). The volume held below the orifice is discharged by evaporation and infiltration (over 6 days). For simplicity, the sides of the pond are assumed to be vertical. The outflow is routed to a nearby stream.

Method: Brown's Trap Efficiency Curve (Source; ref. 23)

Data Requirements: 1) Basin volume
2) Drainage area

Description: An estimate of annual suspended solids removal can be taken from an equation developed by Brown[2,27]. This equation relates sediment trap efficiency to the detention pond volume-drainage area ratio. Brown based his equation on data collected from over 25 normally-ponded reservoirs. The equation is

$$R = 100\left[1 - \left(\frac{1}{1 + 0.1(S/A)}\right)\right] \qquad \text{(I-A1)}$$

where R = annual suspended solids removal, percent,

S = pond volume, acre-ft, and

A = drainage area, mi^2.

The resulting curve is shown in Figure I-A1. The data used to develop equation I-A1 are scattered; thus, the relationship is weak. Also, the S/A ratio provides little measure of the different hydrologic and soil conditions found around the country. Additionally, this equation applies only to reservoirs where some water is held between storms. Nevertheless, with a minimal amount of information, a preliminary estimate is possible. An example application is given below. The same scenario presented earlier is used.

Brown's curve represents the crudest model of sediment removal. It does not distinguish between the removal efficiencies of sands, silts, or clays even though their detention times vary from minutes to months.

Example: The basin capacity and the drainage area are needed to use Brown's equation. The relationship is best used for ponded reservoirs with relatively continuous inflows. The estimated sediment or total suspended solids removal is calculated below. The 600-acre (243 ha) area comprises

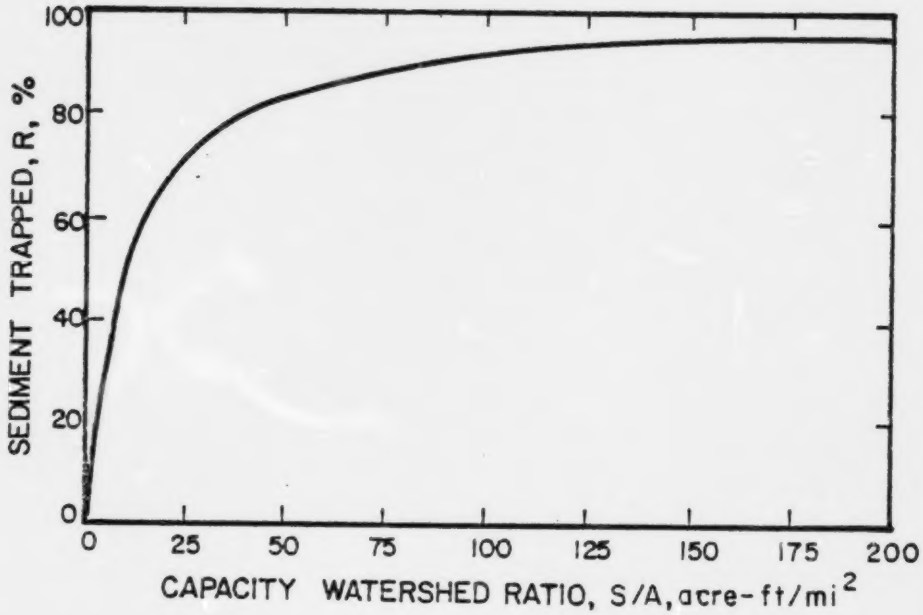


Figure I-A1. Brown's Trap Efficiency Curve (source: ref. 27)

99

0.938 mi^2. Using equation 14, the removal efficiency is

$$R = 100 \left[1 - \left(\frac{1}{1 + 0.1(10 \text{ acre-ft}/0.938 \text{ mi}^2)} \right) \right]$$

$$= 51.6\%$$

Method: Brune's Trap Efficiency Curves (Source: ref. 23)

Data Requirements:
1) Basin volume
2) Basic knowledge physical characteristics of the suspended solids
3) Annual inflow to the basin

Description: A more refined (relative to Brown's curve) set of curves was developed by Brune[3,6,27]. These curves were based on data collected from 44 normally-ponded reservoirs and semi-dry reservoirs located in twenty different states. The curves are shown in Figure I-B1. Rather than basing sediment removal on the volume-drainage area ratio, Brune based his curves on the volume-annual inflow ratio. This ratio provides a rough indicator of detention capability but cannot be defined as an average annual residence time.

Brune's curves provide additional dimensions to the analysis; i.e., a crude accounting of hydrologic conditions (annual inflow) and the physical characteristics of the suspended solids load. The upper curve in Figure I-B1 represents a flow laden with coarse solids (i.e., sand). The lower curve represents a flow in which fine solids (i.e., clay) predominate. The central curve represents a median of the two extremes. Brune's curves have been widely used in sediment basin design, but one caveat is necessary. The data from semi-dry reservoirs did not correlate well with the curves in Figure I-B1; hence, their usefulness is restricted to detention ponds. However, Brune noted in his work that semi-dry reservoirs are likely to achieve much lower removal efficiencies normally-ponded reservoirs.

Example: Brune's curves (like Brown's curve) apply only to normally-ponded reservoirs. Again, for illustrative purposes, the sediment or total suspended solids removal is estimated. Assume that the sediment is characterized by Brune's median curve.

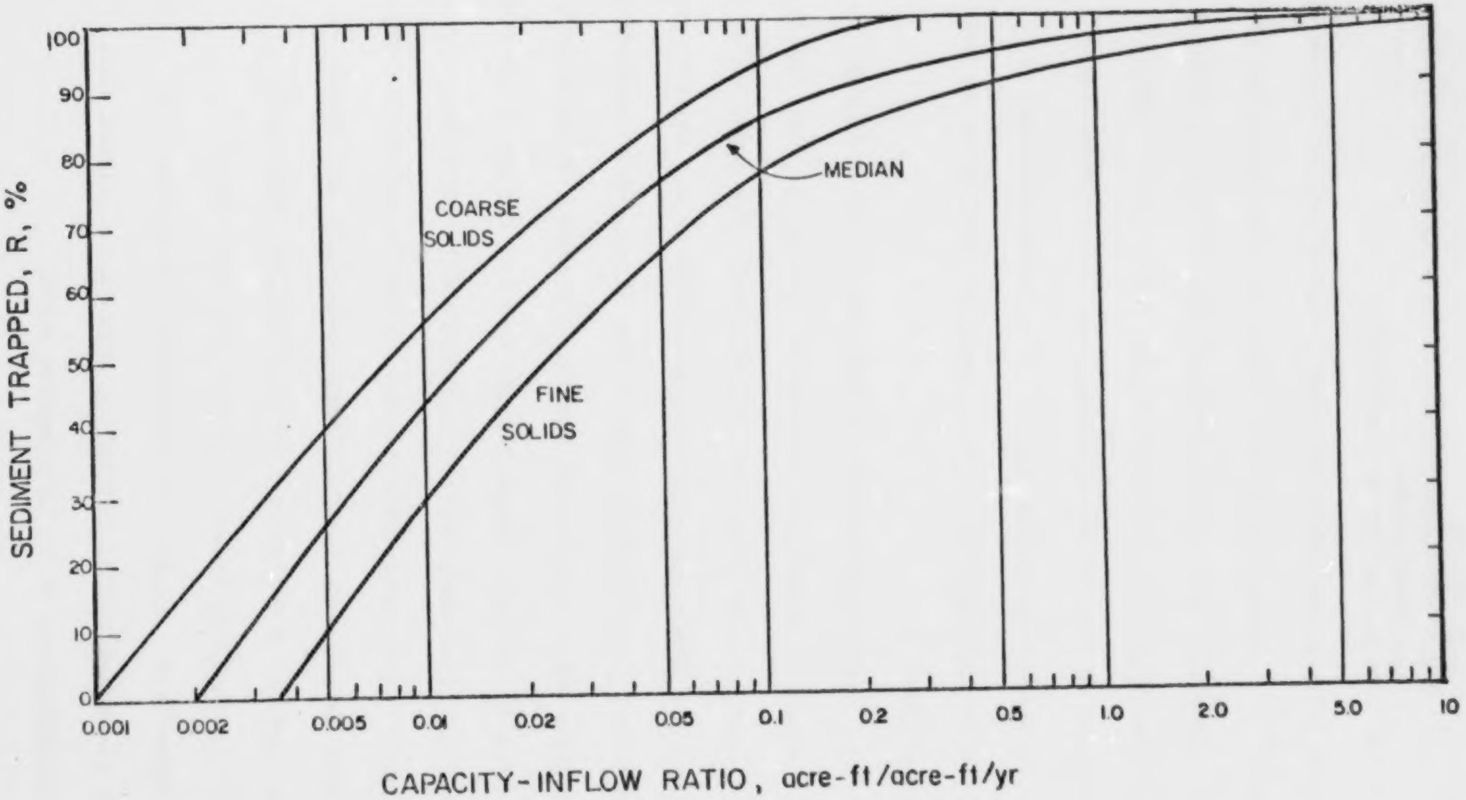


Figure I-Bl. Brune's Trap Efficiency Curves (source: ref. 27)

To use Brune's curves, the capacity-annual inflow ratio must be estimated. The capacity is 10 acre-ft (1235 m^3) and the annual inflow is 8.42 in./yr (21.39 cm/yr) or 421.0 acre-ft (519354 m^3/yr). The capacity-annual inflow ratio is $\frac{10 \text{ acre-ft}}{421.0 \text{ acre-ft/yr}}$ or 0.024 years. From Figure I-B1 the corresponding annual removal percentage is approximately 65%.

Method: Churchill's Trap Efficiency Curve (Source: ref. 23)

Data Requirements:
1) Average cross-sectional area
2) Basin volume
3) Average runoff event flow rate

Description: The method proposed by Churchill[6,7,27] relates the percentage of sediment passing through a reservoir to the "sedimentation index" of the reservoir. The sedimentation index is defined as

$$SI = \left(\frac{S}{Q_R}\right) \div \left(\frac{Q_R}{A_c}\right) \qquad \text{(I-C1)}$$

where SI = sedimentation index, $\sec^2/\text{ft}$,

S = reservoir volume, ft^3,

Q_R = average runoff event flow rate, ft^3/sec, and

A_c = average cross-sectional area of the reservoir, ft^2.

The average cross-sectional area is computed by dividing the reservoir volume by the length of the reservoir (parallel to the flow). If the reservoir has an irregular shape an average length should be used. Churchill's curve is shown in Figure I-C1.

Example: To find the sedimentation index, SI, the average cross-sectional area, A_c, of the basin is required. The length of the basin is 300 feet (91.4 m) and the width is 121 feet (36.9 m). The assumption of a rectangular basin eases the computation of A_c.

$$A_c = \left(\frac{10 \text{ acre-ft}}{300 \text{ ft}}\right) \div \left(\frac{43560 \text{ ft}^2}{\text{acre}}\right)$$

$$= 1452 \text{ ft}^2 \ (135 \text{ m}^2)$$

The average runoff event flow rate is 0.0.46 in/hr. Converting this value to ft^3/sec yields

$$Q_R = (0.0146 \text{ in./hr}) \left(\frac{\text{ft}}{12 \text{ in}}\right) (600 \text{ acres}) \left(\frac{43560 \text{ ft}^2}{\text{acre}}\right)\left(\frac{\text{hr}}{3600 \text{ sec}}\right)$$

$$= 8.8 \text{ ft}^3/\text{sec} \ (0.25 \text{ m}^3/\text{sec})$$

The capacity is 10 acre-feet or 435600 ft^3. Thus, the sedimentation index is

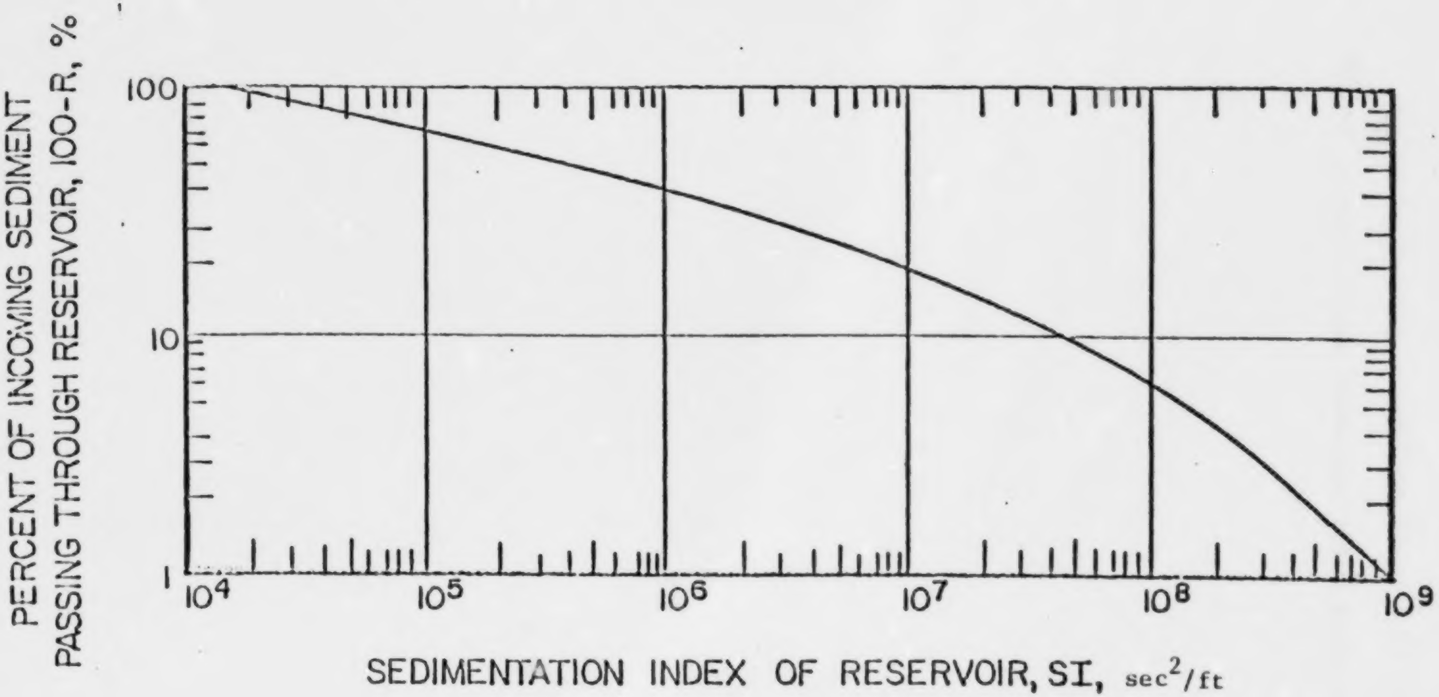


Figure I-C1. Churchill's Trap Efficiency Curve (source: ref. 27)

$$SI = \left(\frac{435600\ \text{ft}^3}{8.8\ \text{ft}^3/\text{sec}}\right) \div \left(\frac{8.8\ \text{ft}^3/\text{sec}}{1452\ \text{ft}^2}\right)$$

$$= 8.2 \times 10^6\ \text{sec}^2/\text{ft}\ (2.7 \times 10^7\ \text{sec}^2/\text{m})$$

From Figure I-C1 the corresponding total suspended solids removal is 100-18% or 82%.

Method: Statistical Moments Method, Sedimentation Tank (Source: ref. 23)

Data Requirements:
1) Surface area of the sedimentation tank
2) Average runoff event flow rate
3) Coefficient of variation for runoff event flow rate

Description: Small and DiToro[25] and Hydroscience[17] have developed a long-term removal equation for stormwater treatment devices based on assumed stochastic distributions of average event flow and pollutant concentrations. These distributions are based on storm relationships shown in Figure I-D1. Sedimentation tanks are viewed differently from other detention facilities as they are not normally designed to provide a significant level of storage. However, this approach may be useful in some cases. The pertinent equation is given as

$$100-R = \frac{1}{W} \iint_{qc} [100-r(c,q)]\ c\ q\ p_c(c)\ p_q(q)\ dc\ dq \qquad \text{(I-D1)}$$

where R = long-term average pollutant removal, percent,

c = runoff event concentration, lb/acre-in.,

q = runoff event flow rate, acre-in/hr,

$r(c,q)$ = percentage pollutant removal by treatment device as a function of c and q,

$p_c(c)$ = probability distribution function of average runoff event pollutant concentration,

$p_q(q)$ = probability distribution function of average event flow, and

W = average pollutant loading to treatment device for all events, lb/hr.

The average flow for each runoff event, q, is assumed to be independent of the average concentration and to have a mean of Q_R, a coefficient of variation ν_q, and a gamma probability distribution function. The probability distribution function of flow is given as

$$p_q(q) = \left(\frac{\kappa}{Q_R}\right)^{\kappa} \left(\frac{q^{\kappa-1}}{\Gamma(\kappa)}\right) e^{-\kappa q/Q_R} \qquad \text{(I-D2)}$$

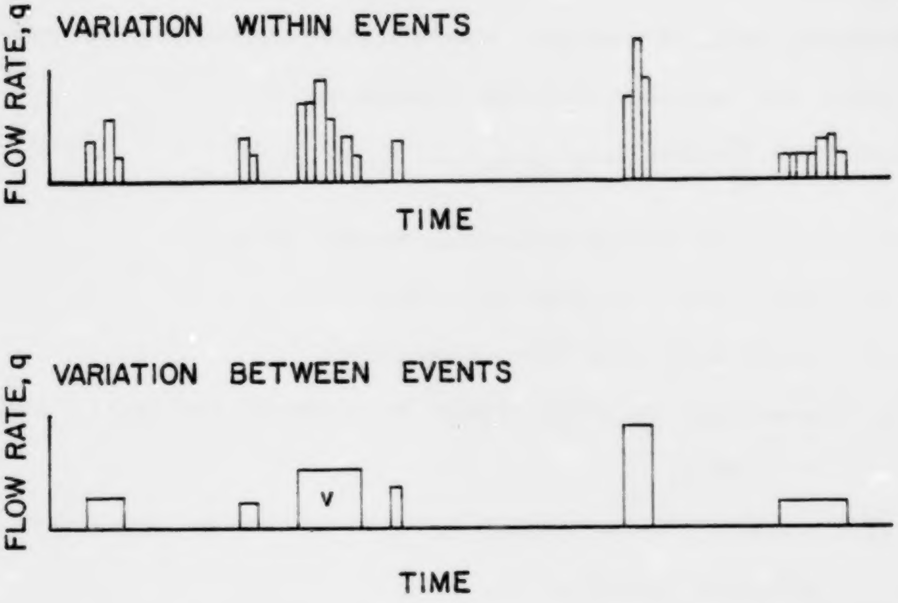


Figure I-D1. Representation of Storm Runoff Process (source: ref. 17)

where $\kappa = 1/\nu_q$, and

$\Gamma(\kappa)$ = the gamma function with argument κ.

The average event concentration, c, with mean C and coefficient of variation ν_c, is also assumed to be distributed according to the gamma distribution function.

If pollution removal is assumed to be a function of flow alone, then equation I-D2 may be simplified to

$$100-R = \frac{C}{W}\int [100-r(q)] \quad q \quad p_q(q)\ dq \qquad \text{(I-D3)}$$

The usefulness of equation I-D3 for sedimentation tanks is enhanced by requiring the average removal for each event to be described by

$$r(q) = a\ e^{-bq/A_s} \qquad \text{(I-D4)}$$

where a = coefficient, $a \leq 100$,

b = coefficient, hr/in., and

A_s = surface area of sedimentation tank, acres.

The term q/A_s can be viewed as an indicator of the "average" overflow rate or detention time for each event (recall earlier discussion). Equation I-D4 requires that depth be relatively constant over the length and width of the facility. Several removal equations for suspended solids are shown in Figure I-D2.

Substituting equations I-D2 and I-D4 into equation I-D3, integrating and solving for R, yields

$$R = a \left[\frac{1}{1 + \frac{bQ_R}{\kappa A_s}} \right]^{\kappa+1} \qquad \text{(I-D5)}$$

Equation I-D5 represents a long-term removal function relating pollutant removal, R, to the average runoff event flow rate. However, the value of R

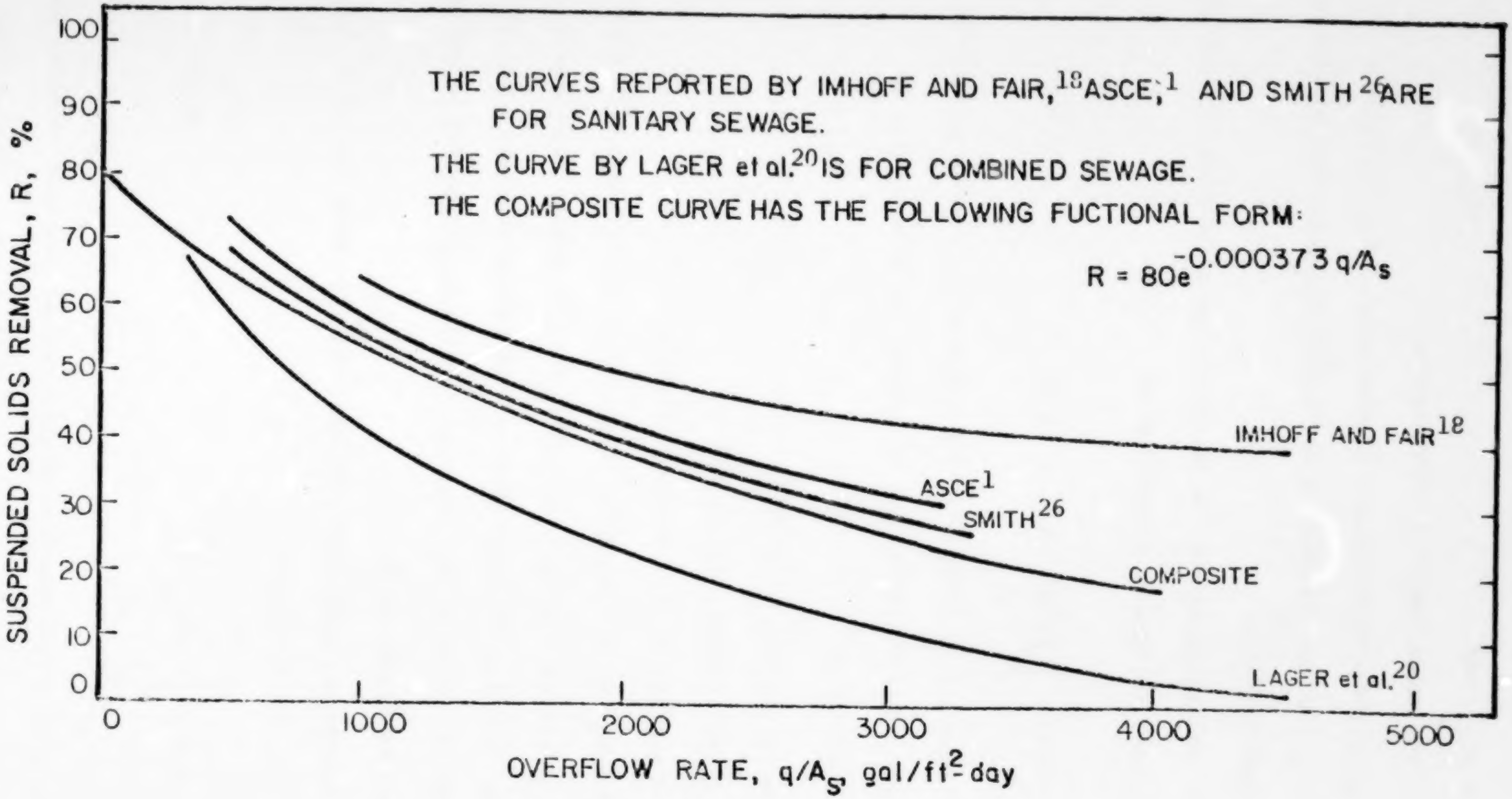


Figure I-D2. Suspended Solids Removal by Detention/Sedimentation (source: ref. 9)

estimated by equation I-D5 is probably conservative because of the additional removal occuring between events. Equations I-D3 through I-D5 assume that the water level in the facility is constant during each storm and that the detention facility remains full between storms (i.e., the level remains at the bottom of an elevated outlet structure between storms). In other words, the basin is essentially a flow-through sedimentation tank and does not provide any significant amount of storage. Thus, this procedure is probably only applicable to basins where the capacity is relatively small when compared to most storm volumes.

The advantage of such an approach is that local hydrologic factors are included in the analysis. Additionally, any pollutant may be investigated. The major drawbacks are obtaining the necessary statistics (i.e., ν_q and Q_R) and the size/flow restriction noted above.

Example: The average event runoff flow rate and the coefficient of variation for the hypothetical drainage area are 0.0146 in/hr or 0.0371 cm/hr and 1.73, respectively (see earlier discussion). Using the composite suspended solids removal function given in Figure I-D2, the long-term average removal percentage is computed as follows:

$$Q_R = (0.0146 \text{ in/hr}) (\text{ft}/12 \text{ in}) (600 \text{ acres}) (43560 \text{ ft}^2/\text{acre}) (24 \text{ hr/d}) (7.48 \text{ gal/ft}^3)$$

$$= 57100000 \text{ gal/d}$$

$$\kappa = 1/\nu_q = 1/1.73 = 0.578$$

$$a = 80.0$$

$$b = 0.000373 \text{ ft}^2\text{-d/gal}$$

$$A_s = 36300 \text{ ft}^2$$

$$R = 80 \left[\frac{1}{1 + \frac{(0.000373 \text{ ft}^2\text{-d/gal})\ (57100000 \text{ gal/d})}{(0.578)\ (36300 \text{ ft}^2)}} \right]^{0.578 + 1}$$

$$= 68.7\%$$

Method: Statistical Moments Method, Storage

Data Requirements:
1) Set of runoff statistics (mean and coefficient of variation of runoff event flow, volume, duration and the time between storms)
2) Basin volume
3) Release rate

Description: Hydroscience, Inc.[17] has developed a set of long-term performance curves for storage basins operated with interevent drawdown pumping. A conceptual view of how such a storage/release configuration operates is shown in Figure I-E1. From this figure and several assumptions, a set of curves relating the mean effective storage capacity, V_E, to the maximum storage capacity, V_B, and the interevent drawdown rate, Ω, was developed. These curves are shown in Figure I-E2. Among the assumptions used to develop this relationship are the following:

1) The runoff flows, q, duration, d, and time between storms, δ, are exponentially distributed and independent (i.e., gamma distributions with $\nu_q = \nu_d = \nu_\delta = 1$).
2) The basin is emptied or drawn down at a constant rate, Ω, between events.
3) Storm volumes exceeding the available basin capacity are by-passed.
4) The available storage capacity for any particular storm, V_e, is the difference between the maximum capacity, V_B, and the volume remaining from the previous storm. The expected value (or long-term mean) of V_e is the mean effective storage capacity, V_E.
5) Storm 1 begins with $V_e = V_E$.
6) The coefficient of variation for runoff event volumes is $\sqrt{3}$.

The curves in Figure I-E2 are normalized over the mean runoff volume, V_R, to enhance their applicability.

The long-term fraction of runoff pollutant load not captured (i.e., discharged with by-passed flows) by the storage basin, f_V, is calculated as the by-passed load, divided by the total load:

$$f_V = \frac{C \displaystyle\int_{q=0}^{\infty} \int_{d=V_E/q}^{\infty} q(d - V_E/q)\, p_d(d)\, p_q(q)\ dd\, dq}{C\, Q_R\, D_R} \qquad \text{(I-E1)}$$

where f_V = long-term fraction of pollutant load not captured,

C = mean runoff pollutant concentration for all events, mass/volume

P_d (d) = probability distribution for runoff event duration, d,

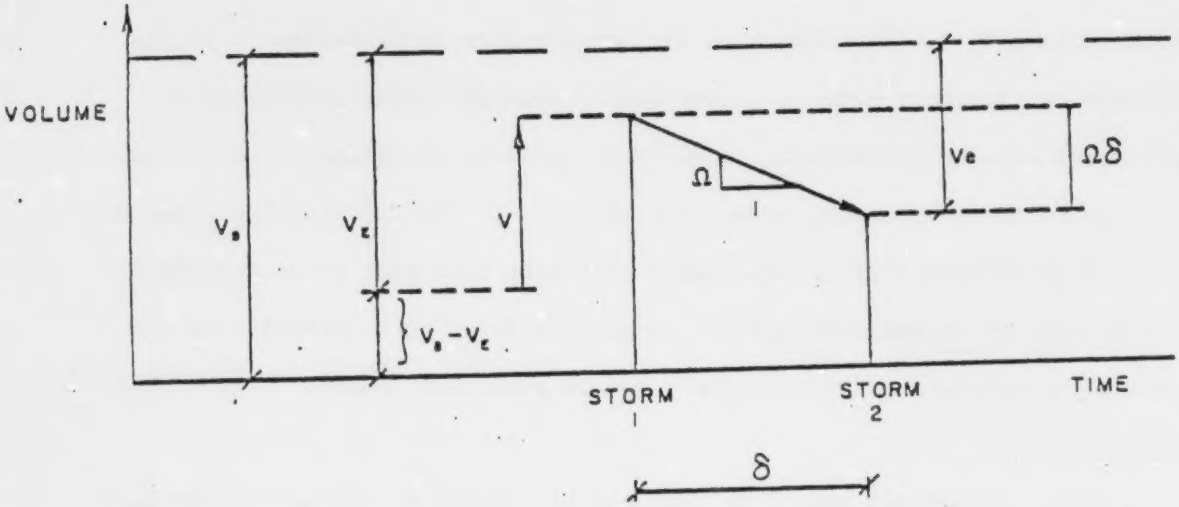
P_q (q) = probability distribution for runoff event flow, q,

Q_R = mean runoff flow for all events, volume/time, and

D_R = mean runoff event duration, time.

Equation I-E1 was numerically integrated to obtain the curves shown in Figure I-E3. The fraction not captured, f_V, is a function of the mean effective storage capacity, V_E, and the coefficient of variation of the runoff volumes, ν_{vR}. Again the mean effective storage capacity, V_E, is normalized over V_R to enhance the applicability of the curves. Note that the runoff concentration is assumed to be independent of runoff flow. This creates a situation in which the runoff concentration is a constant value, C, for all flows and, thus, first-flush effects are ignored. However, Hydroscience [17] developed a set of curves to account for the first-flush effect.

Unfortunately, this method only calculates the fraction of the pollutant load "captured" by the basin, i.e., the load that is not by-passed for some period of time. In order to account for the removal of pollutants a relationship between long-term efficiency and an indicator of detention ability is required. The long-term efficiency is multiplied by the fraction "captured" by the basin to determine the actual level of pollution control.



Legend

V_B = maximum storage capacity

V_E = mean effective storage capacity

V = storm 1 volume

Ω = drawdown rate between storms

V_e = available storage at the start of a storm

δ = time between storm midpoints

Figure I-E1. Conceptualization of Storage Operation (source: ref. 17)

An approach similar to that used by Howard et al.[14] can be used with this method to account for pollution reduction in storage, i.e.,

$$\overline{R} = a \log (DT) + b \qquad \text{(I-E2)}$$

where $\overline{R}$ = long-term pollutant removal efficiency, $0 \leq R \leq 1.0$

a, b = coefficients, and

DT = detention parameter, hr

The definition of DT is purposely left unspecified. Howard et al[14] recommend letting $DT = S/2\Omega$ where S is the basin volume in inches and Ω is the release or treatment rate in inches/hour. However, other indicators of detention ability are probably equally as valid (e.g., basin volume/average inflow, basin volume/total annual inflow, etc.). The coefficients a and b must be determined from an applicable data base such as a cross section of basin data, by calibration against on-site data, or by calibration to the results of a simulator that directly models pollutant removal (e.g. SWMM S/T Block[15]).

Pollutant removal equations need not be limited to the type given by equation I-E2. Other forms are equally permissible as long as they can be used to relate some indicator of detention time and long-term pollutant removal. One possible (and perhaps preferrable) alternative is

$$\overline{R} = \overline{R}_{max}(1 - e^{-K(DT)}) \qquad \text{(I-E3)}$$

where $\overline{R}$ = long-term pollutant removal efficiency, $0 \geq R \geq R_{max}$

$\overline{R}_{max}$ = maximum efficiency, $0 \geq R_{max} \geq 1$,

K = coefficient, 1/hr, and

DT = detention parameter, hr.

The reader is cautioned that the results from batch settling tests are not directly suitable to find values for the coefficients in equations I-E2 or I-E3. In these applications, the critical variable is the elapsed settling time, t_d. The parameter DT is only an indicator of the detention ability

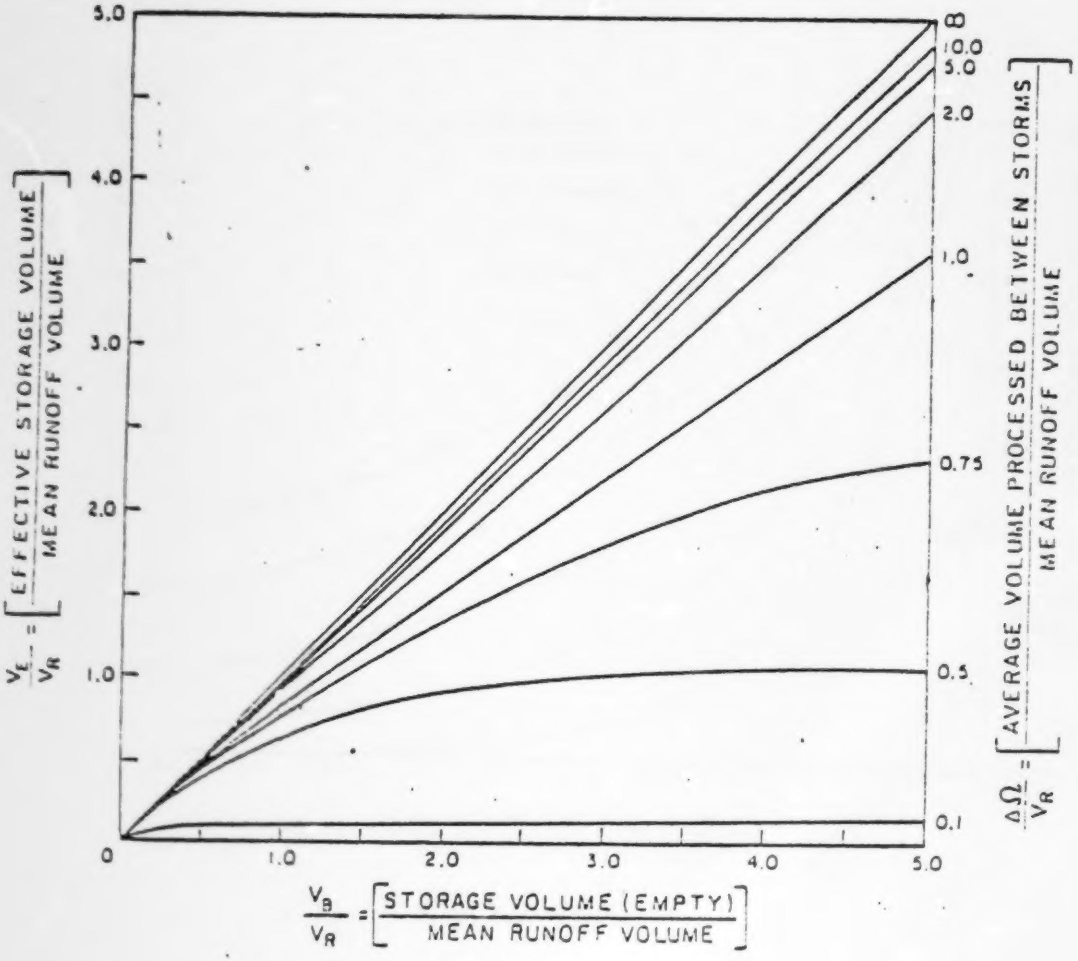


Figure I-E2. Determination of the Mean Effective Storage Capacity, V_E (source: ref. 17)

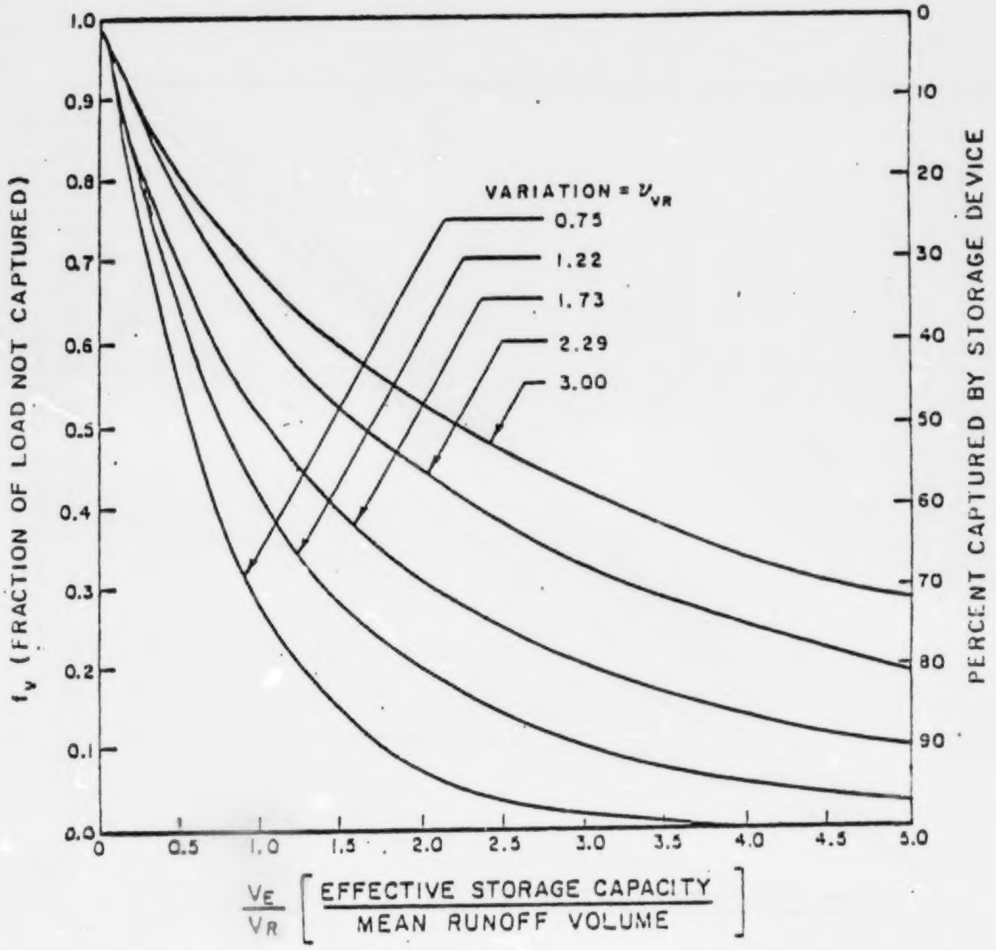


Figure I-E3. Determination of the Long-Term Fraction of the Pollutant Load Not Captured by Storage, f_V (source: ref. 17)

of the basin. On the other hand, t_d is a real-time measure limited to experimental work and simulators capable of tracking the detention time of each water parcel as it passes through a detention basin.

Example: None

Method: Statistical Analysis Method (Source: ref. 14)

Data Requirements:
1) Set of runoff statistics
2) Basin capacity
3) Treatment plant or release rate

Description: The purpose of the statistical analysis method is to obtain closed form expressions for the probability distributions of runoff, overflow and pollution events - expressions which reflect the natural physical processes in the watershed and the effect of man-made facilities and operations. These results can then be used in planning control strategies.

To accomplish this, the watershed has to be represented by a very simple model. Storm events are defined, and the rainfall data are analyzed to obtain the statistics of rainfall probability distributions. Using these distributions and a watershed model, probability distributions of runoff and pollution events are then derived. These distributions form the basis for determining the runoff and pollution control provided by combinations of storage and treatment capacities.

The watershed and facilities are shown schematically in Figure I-E1. Rainfall is the input to the watershed. This input is transformed into runoff, whose temporal behavior depends on that of the rainfall and on the storage and conveyance characteristics of the watershed. The runoff picks up pollution from the watershed and flows into the man-made reservoir. Water is released from the reservoir to the treatment plant, and the treated outflow is discharged into the receiving waters. When the reservoir cannot contain all the runoff, the remainder spills into the receiving waters without going through the treatment plant. Water can also be released after detention in storage into the receiving waters without passing through treatment. This allows the operator to prepare some empty storage when he expects the next storm, releasing into the receiving waters runoff which was already allowed to settle in the reservoir and trapping the first flush of the next storm.

The mathematical method is based on the following propositions and assumptions:

(1) Runoff is generated from the rainfall by first subtracting the depression storage, s_d, and then multiplying the remaining effective precipitation by the runoff coefficient, ϕ.

(2) The concentration of pollution in the runoff waters is constant, independent of the time between storms, rainfall intensity, or time during the storm. Any specified single pollutant (e.g. suspended solids) can be considered.

(3) The treatment plant operates at a constant rate, Ω (in inches/hr), as long as water is in the reservoir. This treatment rate is assigned to storm runoff only, i.e., it is the capacity of the sewage treatment plant above that needed to treat dry weather flows as it is a separate wet-weather plant.

(4) The efficiency of the treatment plant, η_Ω, is constant.

(5) The storage reservoir has a treatment efficiency, η_s, which is due to the residence time of water in it. This efficiency is estimated as

$$\eta_s = a \log (DT) + b, \qquad RT \leq RTMIN \qquad \text{(I-F1)}$$

where (a) and (b) are empirically determined coefficients and RTMIN is some reasonable minimum value of DT above which equation I-F1 is valid. The value of DT, the detention parameter, is estimated as $S/2\Omega$ where S is the basin capacity (in inches).

(6) The bypass overflow receives no treatment, and therefore enters into the receiving waters with the original pollutant concentration.

(7) Runoff enters the reservoir at a constant rate for the approxi-

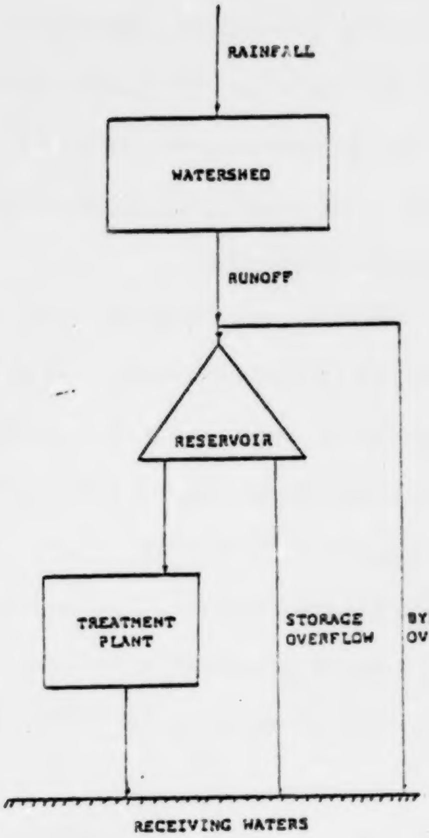


Figure I-F1. Schematic Representation of the System Used by the Statistical Analysis Method (source: ref. 14)

mate duration of the rainfall, i.e. the temporal distribution of inflow to the reservoir is not affected by routing on the watershed or in the pipes.

(8) The reservoir is assumed to be full at the end of the previous storm.

Example: None

Method: Corps of Engineer's STORM model (Source : ref. 16)

Data Requirements:
1) Long-term hourly rainfall record
2) Drainage area characteristics (imperviousness, depression storage)
3) Basin volume
4) Treatment plant or release rate

Description: Figure I-G1 shows a schematic representation of the seven storm water elements modeled by STORM. In this approach, rainfall washes dust and dirt and the associated pollutants off the watershed. The resulting runoff is routed to the treatment-storage facilities where runoff less than or equal to the treatment rate is treated and released. Runoff exceeding the capacity of the treatment plant is stored for treatment at a later time. If storage is exceeded, the untreated excess is wasted through overflow directly into the receiving waters. The magnitude and frequency of these overflows are often important in a storm water study. STORM provides statistical information on washoff, as well as overflows. The quantity, quality, and number of overflows are functions of hydrologic characteristics, land use, treatment rate, and storage capacity.

Computations of treatment, storage, and overflow are accomplished on an hourly basis throughout the rainfall/snowmelt record. Periods of no rain are skipped. The number of dry hours is used for various purposes including recovery of soil moisture storage capability. Every hour in which runoff (may include dry-weather flow) occurs, the treatment facilities are utilized to treat as much runoff as possible. When the runoff rate exceeds the treatment rate, storage is utilized to contain the runoff. When runoff is less than the treatment rate, the excess treatment rate is utilized to diminish the storage level. If the storage capacity is exceeded, all excess runoff is considered overflow and does not pass through the storage facility. This overflow is lost from the system and cannot be treated later. While the storm runoff is in storage its age is increasing.

Various methods of aging are used including average, first-in: last-out, first-in: first out, or others, depending on the inlet and outlet configurations of the storage reservoir. STORM does not compute the amount of pollutant reductions due to settlement of solids while in storage.

An approach similar to that used by Howard et al.[14] can be used with STORM to account for pollution reduction in storage, i.e.,

$$R = a \log (DT) + b \qquad \text{(I-G1)}$$

where R = long-term pollutant removal efficiency, $0 \geq R \geq 1.0$

a, b = coefficients, and

DT = detention parameter, hr

The definition of DT is purposely left unspecified. Howard et al.[14] recommend letting DT = S/2T where S is the basin volume in inches and T is the release or treatment rate in inches/hour. However, other indicators of detention ability are probably equally valid (e.g., basin volume/average inflow, basin volume/total annual inflow, etc.). The coefficients a and b must be determined from an applicable data base such as a cross section of basin data, by calibration against on-site data, or by calibration to the results of a simulator that directly models pollutant removal (e.g., SWMM S/T Block[15]).

Pollutant removal equations need not be limited to the type given by equation I-G1. Other forms are equally permissible as long as they can be used to relate some indicator of detention time to long-term pollutant removal. One possible (and perhaps preferable) alternative is

$$\overline{R} = \overline{R}_{max}(1 - e^{-k(DT)}) \qquad \text{(I-G2)}$$

where $\overline{R}$ = long-term pollutant removal efficiency, $0 \leq R \leq \overline{R}_{max}$

$\overline{R}_{max}$ = maximum efficiency, $0 \leq R_{max} \leq 1$,

K = coefficient, 1/hr, and

DT = detention parameter, hr.

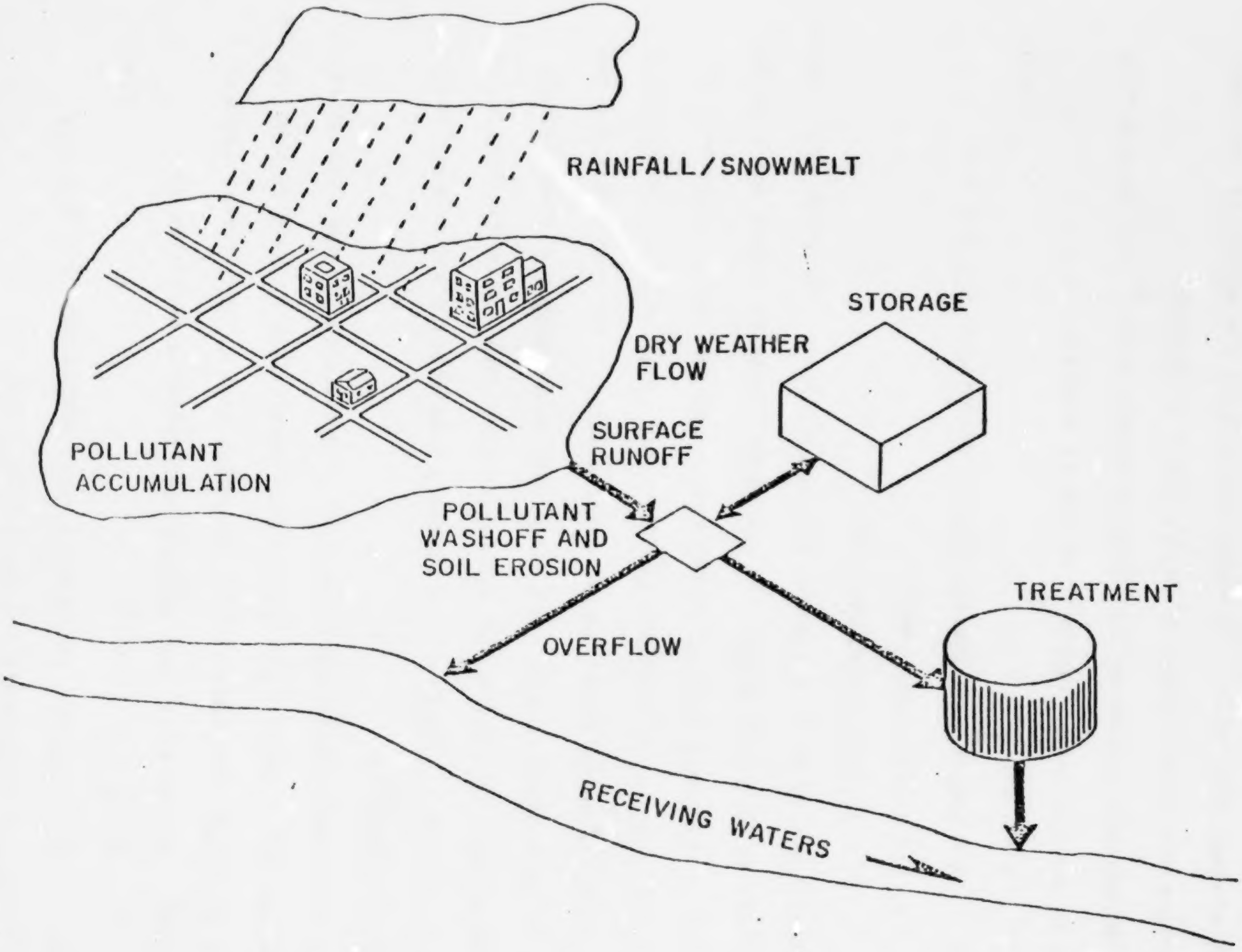


Figure I-G1. Major Processes Modeled by STORM (source: ref. 16)

The reader is cautioned that the results from batch settling tests are not directly suitable to find values for the coefficients in equations I-G1 and I-G2. In these applications, the critical variable is the elasped settling time, t_d. The parameter DT is only an indicator of the detention ability of the basin. On the other hand, t_d is a real-time measure limited to experimental work and simulators capable of tracking the detention time of each water parcel as it passes through a detention basin.

The long-term pollutant removal efficiency is multiplied by the estimate of pollutant "capture" provided by the model to determine the overall level of pollution control. Pollutant capture is defined as the fraction (on an annual basis) of the pollutant load passing through the storage-treatment system.

Example: None

Method: SWMM Storage/Treatment Block (Source: ref. 23 and ref. 15)

Data Requirements:
1) Basin geometry and outlet hydraulics
2) Pollutant removal equation or particle size distribution
3) Flow and pollutant concentration time series (from measurements and/or another simulator)
4) Evaporation rates

Description: The University of Florida[15] has developed the Storage/Treatment (S/T) Block as part of the extensive EPA Storm Water Management Model (SWMM). The S/T Block is a flexible simulator capable of modeling several storage/treatment units, including detention facilities. The model has several advantages, among them:

1) the ability to model a wide variety of detention facility geometries and outlet structures;
2) sludge accounting;
3) the capability for dry-weather drawdown;
4) it is readily interfaced with the other blocks of SWMM (which have the ability to simulate stormwater discharges from a variety of drainage areas);
5) pollutants may be characterized by particle size/specific gravity distributions;
6) a wide variety of time-varying pollutant removal equations may be used;
7) any pollutant may be simulated; and
8) it is the most versatile model available.

The model lacks the ability, however, to model the resuspension of settled particles. Basins may be modeled as completely-mixed or plug flow reactors: intermediate (arbitrary flow) modes are not available. A detailed description of the SWMM Storage/Treatment Block is given by Huber et al.[15].

For complete mixing, the concentration of the pollutant in the unit is assumed to be equal to the effluent concentration. The mass balance equation for the assumed well-mixed, variable-volume reservoir shown in Figure I-H1 is [22]:

$$\frac{d(VC)}{dt} = I(t)\ C^I(t) - O(t)\ C(t) - K\ C(t)\ V(t) \qquad \text{(I-H1)}$$

where V = reservoir volume, ft^3,

C^I = influent pollutant concentration, mg/l,

C = effluent and reservoir pollutant concentration, mg/l,

I = inflow rate, ft^3/sec,

O = outflow rate, ft^3/sec,

t = time, sec, and

K = decay coefficient, sec^{-1}.

Equation I-H1 is very difficult to work with directly. It may be approximated by writing the mass balance equation for the pollutant over the interval, Δt:

$$\text{Change in mass in basin} = \text{Mass entering during } \Delta t - \text{Mass leaving during } \Delta t - \text{Decay during } \Delta t$$

$$C_2V_2 - C_1V_1 = \frac{C_1^I\ I_1 + C_2^I\ I_2}{2}\ \Delta t - \frac{C_1O_1 + C_2O_2}{2}\ \Delta t - K\ \frac{C_1V_1 + C_2V_2}{2}\ \Delta t \qquad \text{(I-H2)}$$

where subscripts 1 and 2 refer to the beginning and end of the time step, respectively.

From a separate flow-routing procedure (the Puls method[27]), I_1, I_2, O_1, O_2, V_1, and V_2 are known. The concentration in the reservoir at the beginning of the time step, C_1, and the influent concentrations, C_1^I and C_2^I are also known as are the decay rate, K, and the time step, Δt. Thus, the only unknown, the concentration at the end of the time step, C_2, can be found di-

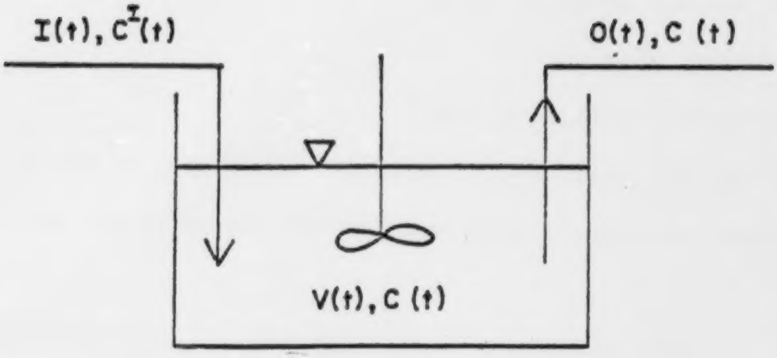


Figure I-H1. Well-Mixed, Variable-Volume Reservoir (source: ref. 24)

130

Table I-H1. Detention Facility Performance, S/T Block (source: ref. 23)

```
UNIT PERFORMANCE SUMMARIES FOR YEAR 1971


******** SUMMARY FOR UNIT #  1,    DETENTION BASIN     ********

                FLOW          FLOW       SUS.SOLIDS  SUS.SOLIDS       BOD            BOD
                (CF)      % TOT % TRT      (LBS)     % TOT % TRT     (LBS)      % TOT % TRT
             ----------   ----- -----  ----------    ----- -----  ----------    ----- -----
INFLOW,TOT   0.1675E+08                0.3571E+06                0.5404E+05
BYPASS       0.0            0.0        0.0             0.0       0.0             0.0
INFLOW,TRT   0.1675E+08 100.0          0.3571E+06  100.0         0.5404E+05  100.0
OUTFLOW      0.1650E+08  98.5   98.5   0.1475E+06   41.3   41.3  0.3600E+05   66.6   66.6
RESIDUALS    0.0            0.0    0.0 0.0             0.0    0.0 0.0             0.0    0.0
REMAINING    0.2189E+06     1.3    1.3 0.2094E+06   58.6   58.6  0.1802E+05   33.3   33.3
EVAP. LOSS   0.3193E+05     0.2    0.2
```

Reproduced from
best available copy.

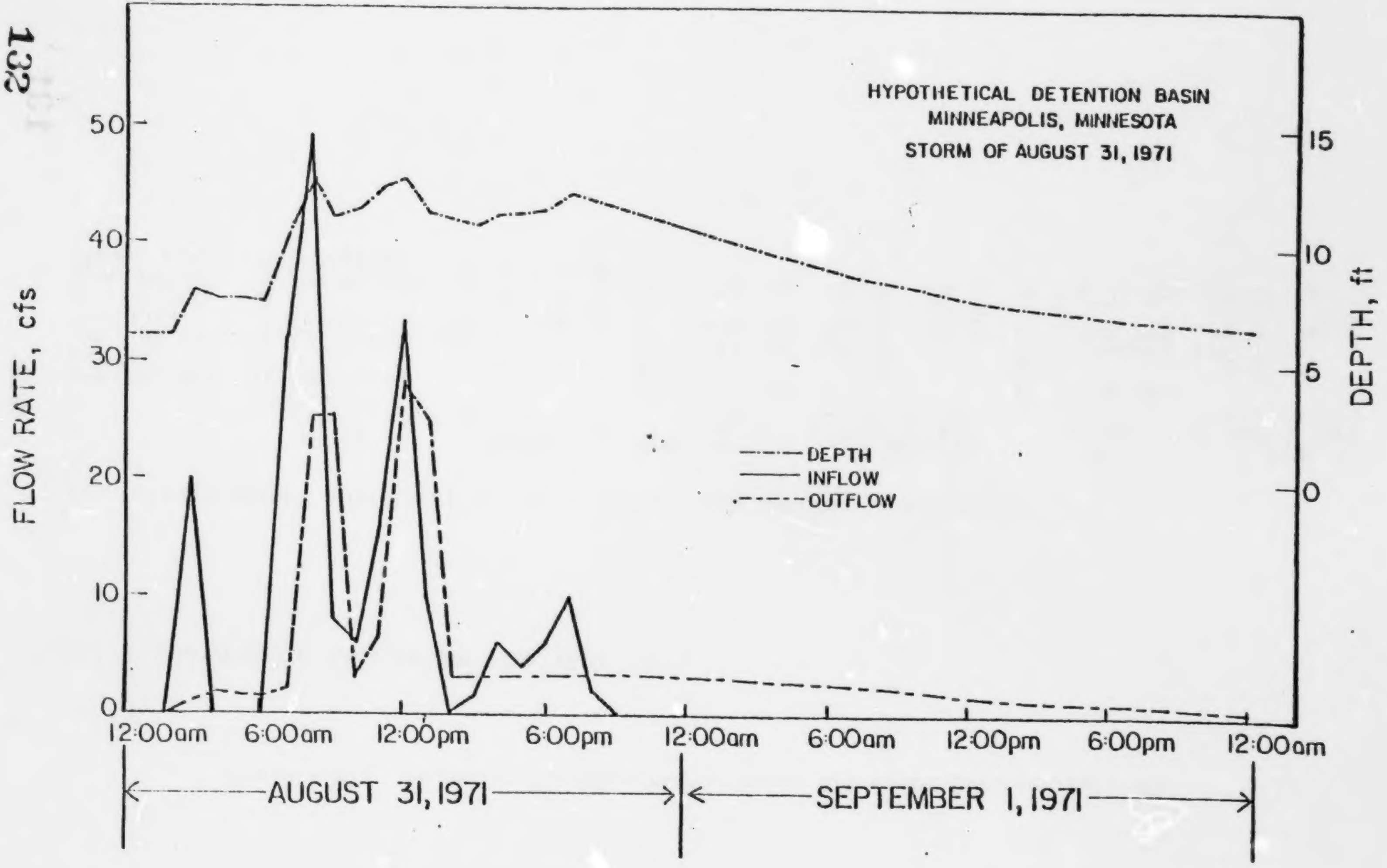


Figure I-112. Detention Facility Quantity Performance, Storm of August 31, 1971, S/T Block (source: ref. 23)

rectly by rearranging equation I-H2 to yield

$$C_2 = \frac{C_1V_1 + \frac{(C_1^I\ I_1 + C_2^I\ I_2)}{2}\ \Delta t - \frac{C_1O_1}{2}\ \Delta t - \frac{K\ C_1V_1}{2}\ \Delta t}{V_2(1 + \frac{K\ \Delta t}{2}) + \frac{O_2}{2}\ \Delta t} \qquad \text{(I-H3)}$$

Equation I-H3 is the basis for the complete mixing model of pollutant routing through a detention unit.

Equations I-H1, I-H2, and I-H3 assume that pollutants are removed at a rate proportional to the concentration present in the unit. In other words, a first-order reaction is assumed. The coefficient K is the rate constant -- it represents the fraction of pollutant removed per unit of time. Thus, the product of K and Δt represents the fraction removed during a time step, R. The user controls the value of R through the use of a user-supplied removal equation (see Equation I-H6 and accompanying discussion).

Removed pollutant quantities are not allowed to accumulate in a completely-mixed detention unit. Strictly, pollutants cannot settle under such conditions. All pollutant removal is assumed to occur by other means, such as biological decomposition. Several processes such as flocculation and rapid-mix chlorination are essentially completely-mixed detention units.

If the user selects the plug flow option, the inflow during each time step, herein called a plug, is labeled and queued through the detention unit. Transfer of pollutants between plugs is not permitted. The outflow for any time step is comprised of the oldest plugs, and/or fractions thereof, present in the unit. This is accomplished by satisfying continuity for the present outflow volume (calculated by the Puls flow-routing procedure[27]):

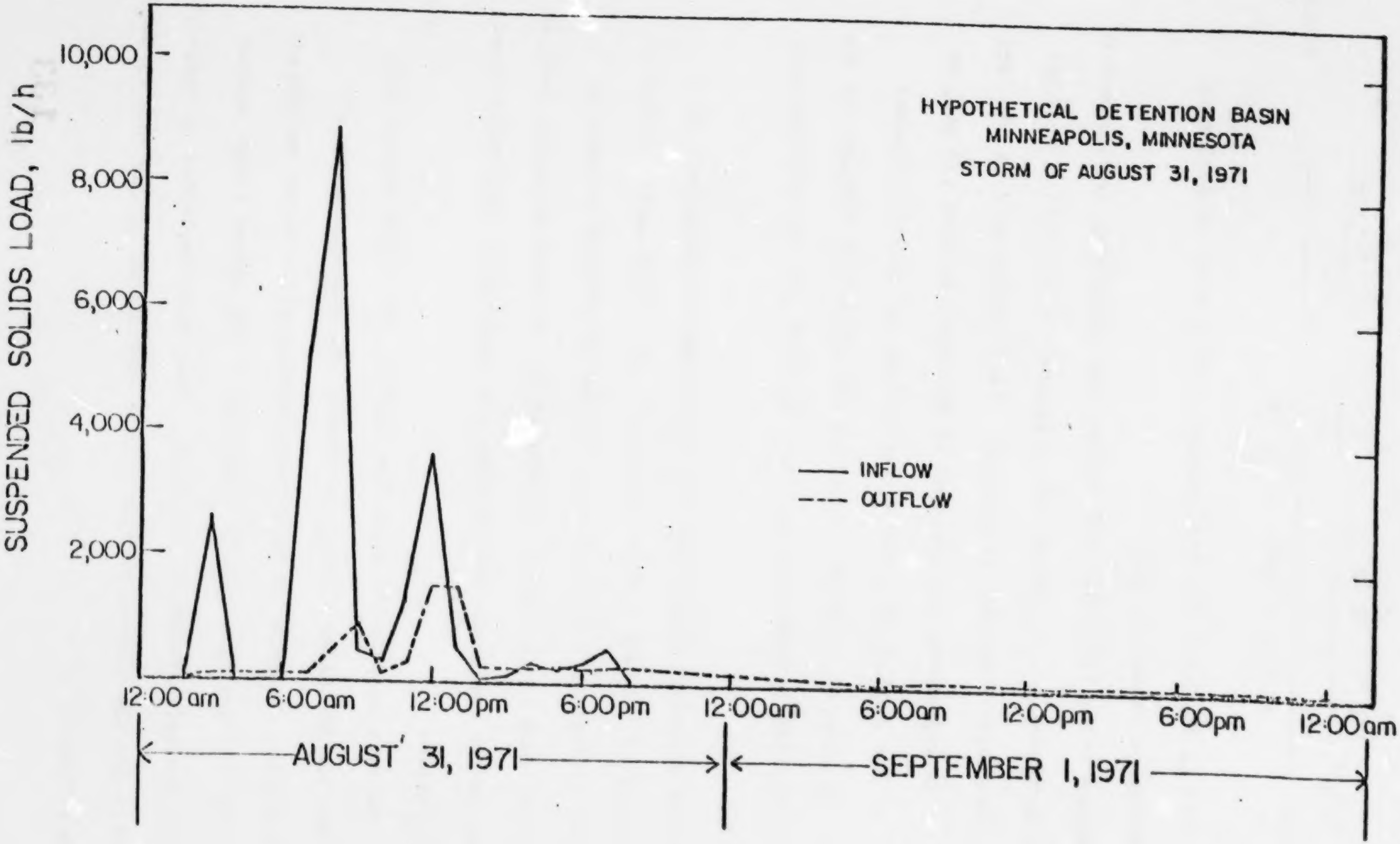


Figure I-113. Detention Facility Quality Performance, Storm of August 31, 1971, S/T Block (source: ref. 23)

$$\sum_{j=JP}^{LP} V_j \div f_j = V_o \qquad \text{(I-H4)}$$

where V_o = volume leaving unit during the present time step, ft^3,

V_j = volume entering unit during the j^{th} time step (plug j), ft^3,

f_j = fraction of plug k that must leave the unit to satisfy continuity with V_o, $0 \leq f_j \leq 1$,

JP = time step number of the oldest plug in the unit, and

LP = time step number of the youngest plug required to satisfy continuity with V_o.

Removal equations are specified by the user (see later discussion) and, in most cases, should be written as a function of detention time (along with other possible parameters). The detention time for each plug j is calculated as

$$(t_d)_j = (KKDT - j)\,\Delta t \qquad \text{(I-H5)}$$

where KKDT = present time step number.

Removal of any pollutant may be simulated as a function of detention time, the time step size, its influent concentration, the removal fractions of pollutants, and/or the influent concentrations of other pollutants. This selection is left to the user but there are some restrictions (depending on the basin type). A single, flexible equation is provided by the program to construct the desired removal equation:

$$R = \left(a_{12}\exp[a_1x_1]x_2^{a_2} + a_{13}\exp[a_3x_3]x_4^{a_4} + a_{14}\exp[a_5x_5]x_6^{a_6} + a_{15}\exp[a_7x_7 + a_8x_8]x_9^{a_9}x_{10}^{a_{10}}x_{11}^{a_{11}}\right)^{a_{16}} \qquad \text{(I-H6)}$$

where x_i = removal equation variables,

a_j = coefficients, and

R = removal fraction, $0 \leq R \leq 1.0$.

The user assigns the removal equation variables, x_i, to specific program variables (detention time, flow rate, etc.). If an equation variable is not assigned it is set equal to 1.0 for the duration of the simulation. The values of the coefficients, a_j, are directly specified by the users. There is considerable flexibility contained in equation I-H6 and, with a judicious selection of coefficients and assignment of variables, the user probably can create the desired equation. An example is given below.

An earlier version of the Storage/Treatment Block employed the following removal equation for suspended solids in a sedimentation tank[12]:

$$R_{SS} = R_{max}(1 - e^{-Kt_d}) \qquad \text{(I-H7)}$$

where R_{SS} = suspended solids removal fraction, $0 \leqq R_{SS} \leqq R_{max}$,

R_{max} = maximum removal fraction,

t_d = detention time, sec, and

K = decay coefficient, $\sec^{-1}$.

This same equation could be built from equation I-H6 by setting $a_{12} = R_{max}$, $a_{13} = -R_{max}$, $a_3 = -K$, $a_{16} = 1.0$, and letting x_3 = detention time, t_d. All other coefficients, a_j, would equal zero.

Treatability studies can help determine the value of decay coefficients (See Appendix II). Ideally, there would also be some flow and pollutant concentration measurements (for the influent and effluent, concurrently) for an adequate calibration. However, if treatability data are the only source of performance data, the model could probably generate a reasonable estimate of long-term performance.

Example: The Storage/Treatment (S/T) Block of the Storm Water Management Model was used to simulate the hypothetical detention facility described earlier. A year of flow and pollutant concentration data were generated using the Corps of Engineers' STORM model and linked to the S/T

Block through an interfacing program. These data were generated from the land use information provided in the general example description and the Minneapolis precipitation record for 1971. Based on a frequency analysis of 25 years of precipitation records, Heaney et al.[11] selected 1971 as a fairly typical year for Minneapolis. The basin was modeled as a plug-flow unit and a relationship identical to equation I-H7 was used to remove suspended solids and BOD_5. The value of R_{max} was set at 0.65 and 0.35 for suspended solids and BOD_5, respectively, and the value of K equalled 0.0003 sec^{-1} in both cases. The results are summarized in Table I-H1. The suspended solids removal is 58.7 percent and the BOD_5 removal is 33.4 percent.

A simulator provides an extra benefit in that specific periods can be investigated in more detail. The behavior of the facility during the storm of August 31, 1971 is shown in Figure I-H2. The total rainfall for this storm was 1.19 in. (3.02 cm). A scan of the results shows the expected response. The peak flows are substantially reduced and discharged over a significantly longer period than that of the inflows. In this particular case, the discharges are very high when the water depth in the basin exceeds 12 ft (the depth at the bottom of the weir) and very low between 6 ft and 12 ft (orifice discharge). A substantial reduction in the suspended solids loading is also evident.

Method: Other Simulation Methods (Source: ref. 23)

Data Requirements: Variable; generally requires basin geometry, outlet structure, pollutant removal coefficients and inflow time series.

Description; In a report by the City of Milwaukee[8] concerning the design of the Humboldt Avenue detention basin, a simple model was developed to aid in the analysis. In this model, the basin is treated as a constant-volume, plug-flow reactor and pollutants are removed as a function of detention time (i.e., the length of time a plug of water remains in the basin). No provisions are made for solids characteristics (i.e., particle size distribution), resuspension of settled material, sludge build-up or varying outlet structures. Despite its simplicity, the model admirably performed the required tasks.

A more advanced model developed by Ward et al.[28] was given the acronym DEPOSITS. It is designed to simulate sediment detention basins but is readily adaptable to urban stormwater detention facilities. Again, the detention facility is modeled as a plug-flow reactor. In this case, sediment is removed by simulating the settling of particles and a particle size/specific gravity distribution is required. In contrast to the Milwaukee model, DEPOSITS is capable of simulating the facility as a variable surface area and volume unit. The model also accounts for the effects of sediment (sludge) build-up. It is not intended for long-term simulations.

Medina[22] constructed a detention facility model by solving the differential equations governing the movement of flow and pollutants through well-mixed detention basins. The solutions, containing complex integrals, are directly useable if simple forcing functions (inflow hydrographs and pollutographs) are assumed. However, these forcing functions are rarely simple and, in fact, contain a substantial random element. Thus, direct solutions are nearly impossible to achieve. This difficulty is overcome by evaluating the solution at discrete intervals and assuming a constant forcing function over each interval. This method is applicable to constant and variable volume facilities. Unfortunately, the model is limited to a linear relationship between volume and outflow.

Appendix II: Treatability Studies for Detention Basins

Several NURP studies are evaluating the removal efficiencies of stormwater detention ponds. Data on the performance of these ponds are very scarce. Whipple and Hunter[29] have examined the settleability of urban runoff pollution. Their data will be used to describe a relatively general procedure for summarizing the results of a treatability study. Figure II-1 shows their settleability data for hydrocarbons. The usual assumption in environmental engineering is that pollutant removal follows first-order kinetics. If this is the case then the equation for hydrocarbon removal can be represented by

$$c/c_o = e^{-kt} \qquad \text{(II-1)}$$

where c = hydrocarbon concentration at any time t, mg/l,

c_o = initial hydrocarbon concentration, mg/l,

t = detention time, hr, and

k = rate constant, hr^{-1}.

Taking the logarithm of equation (1) yields

$$\ln(c/c_o) = -kt \qquad \text{(II-2)}$$

Thus, a plot of the data on semi-log paper should yield a straight line with a slope of $-k$. Unfortunately, the data do not plot as a straight line on semi-log paper (see Figure II-2) indicating that the assumption of first-order kinetics, in this case, is inappropriate. A primary reason for the popularity of assuming first-order kinetics is that the resulting solution is so simple. Removal efficiencies are independent of initial concentrations. However, first-order kinetics may provide a reasonable approximation if the range of times is relatively short. For example, first-order kinetics can be assumed to hold for the hydrocarbon data as long as the detention times are less than about eight hours (see Figure II-2). One could next try second-order kinetics, or third order, or zero order. Fortunately,

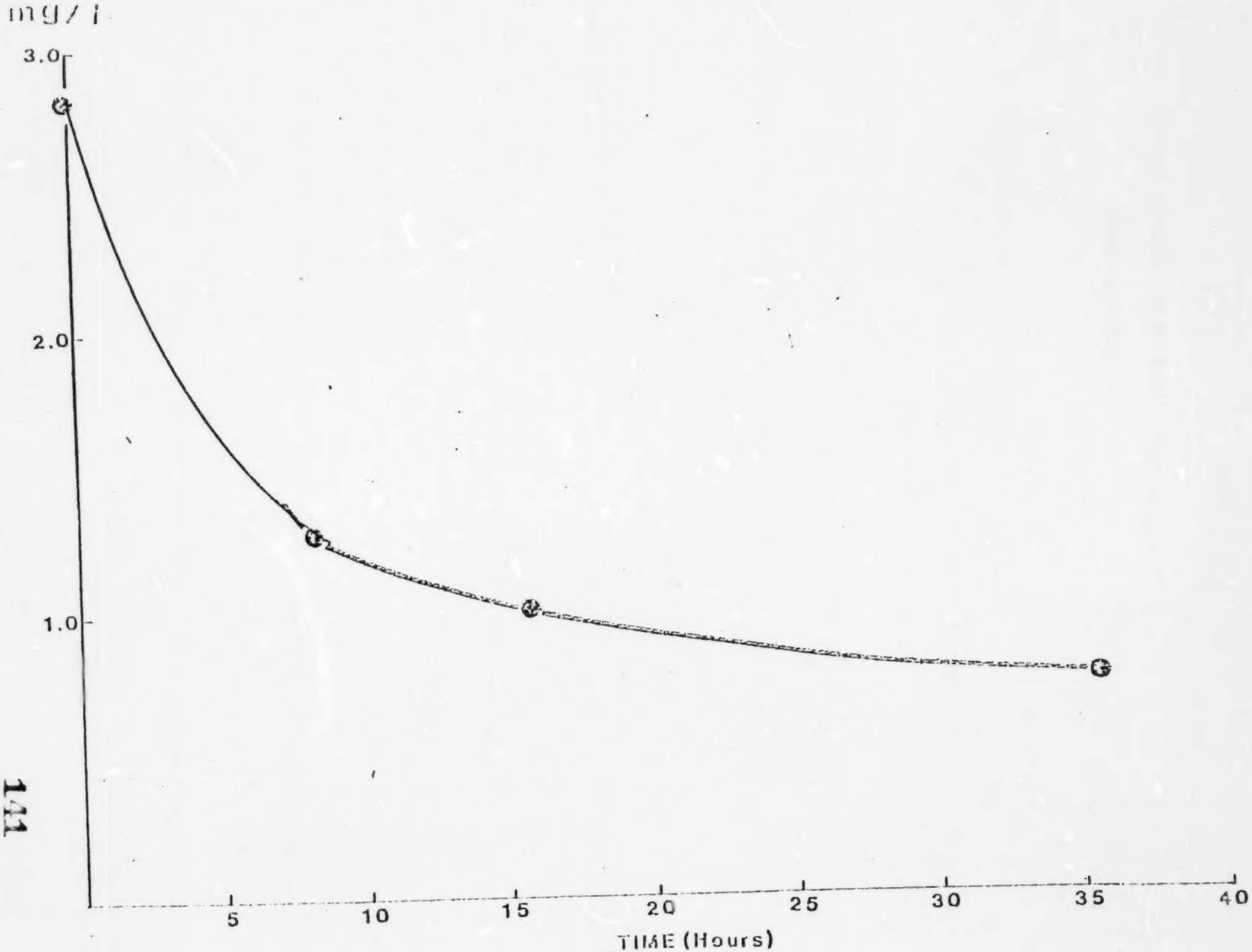


Figure II-1. Settleability of Hydrocarbons, Lawrenceville Shopping Center (source: ref. 28)

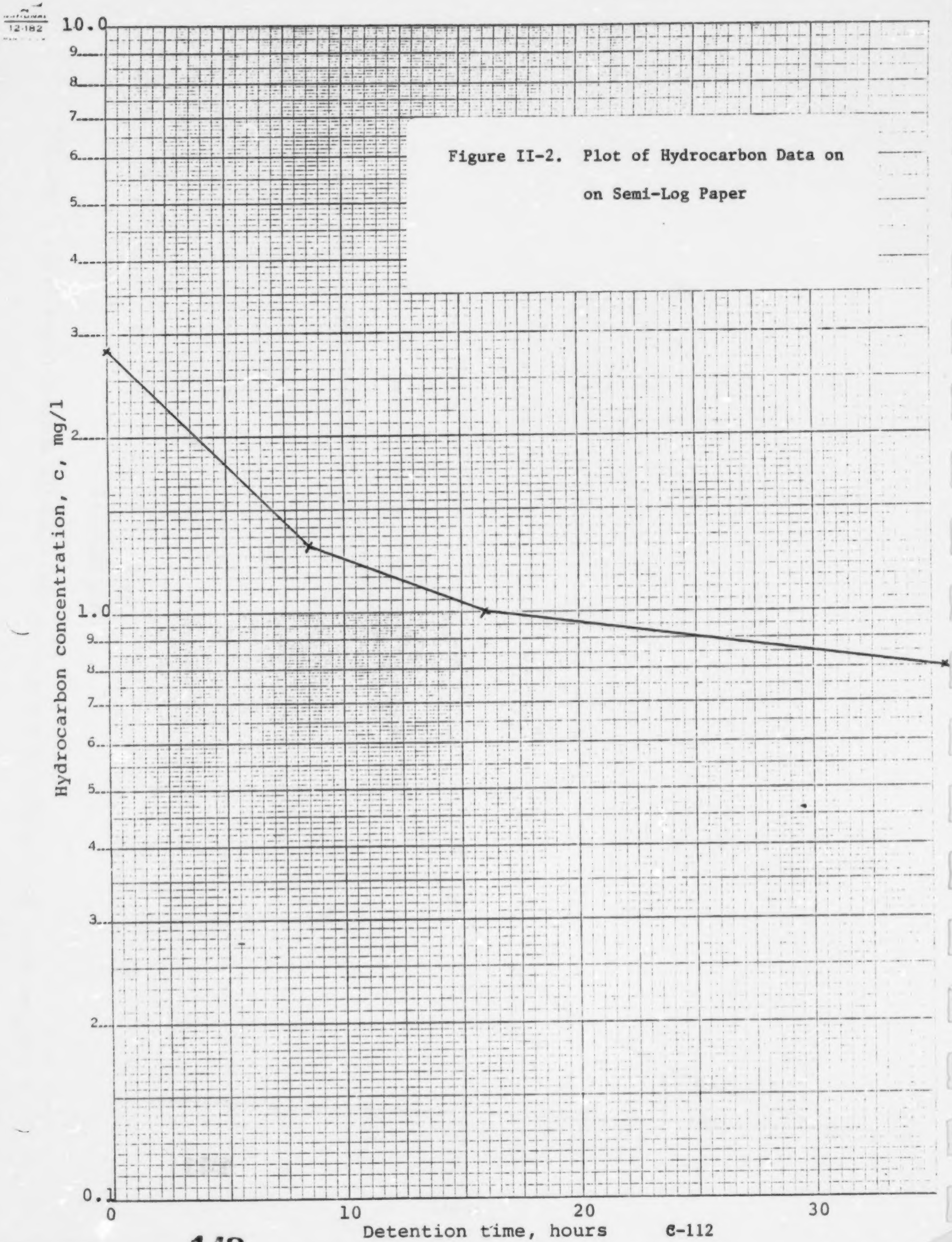


Figure II-2. Plot of Hydrocarbon Data on on Semi-Log Paper

a more general approach exists wherein the order can assume non-integer values.

The rate of reaction and concentration of reactant can be related as follows:

$$-\frac{dc}{dt} = r = k\ c^n \qquad \text{(II-3)}$$

where
r = reaction rate,
k = rate constant,
c = concentration of reactant, and
n = reaction order.

Using equation II-3, the reaction order can be found by plotting reaction rate, $r = dc/dt$, versus concentration, c, as shown in Figure II-3. Technically, the above procedure is called the differential method for determining the reaction order for isothermal irreversible reactions in a perfectly mixed, constant volume reactor (see Levenspiel[21], Hill[12], Holland and Anthony[13], and/or Butt[4] for details). The expression for the proportion remaining can be found for any n by solving

$$r = -dc/dt = k\ c^n \qquad \text{(II-4)}$$

Integrating equation II-4 yields

$$c/c_o = [1 + (n-1)c_o^{\ n-1}\ kt]^{\frac{1}{1-n}} \qquad n \neq -1 \qquad \text{(II-5)}$$

For the hydrocarbon data, $k = 0.037$, $n = 1.90$ (see Figure II-3), and c_o = 2.8 mg/l. Substituting into equation II-5 yields

$$c/c_o = [1 + (1.90-1)2.8^{(1.90-1)}\ (.037)t]^{\frac{1}{1-1.90}}, \text{ or}$$

simplifying,

$$c/c_o = [1 + .0842t]^{-1.11} \qquad \text{(II-6)}$$

Equation II-6 can be spot checked by trying a few trial values of t.

t, hr.	$(c/c_o)_{meas.}$	$(c/c_o)_{calc.}$
5	0.62	0.68
15	0.36	0.40
25	0.30	0.28

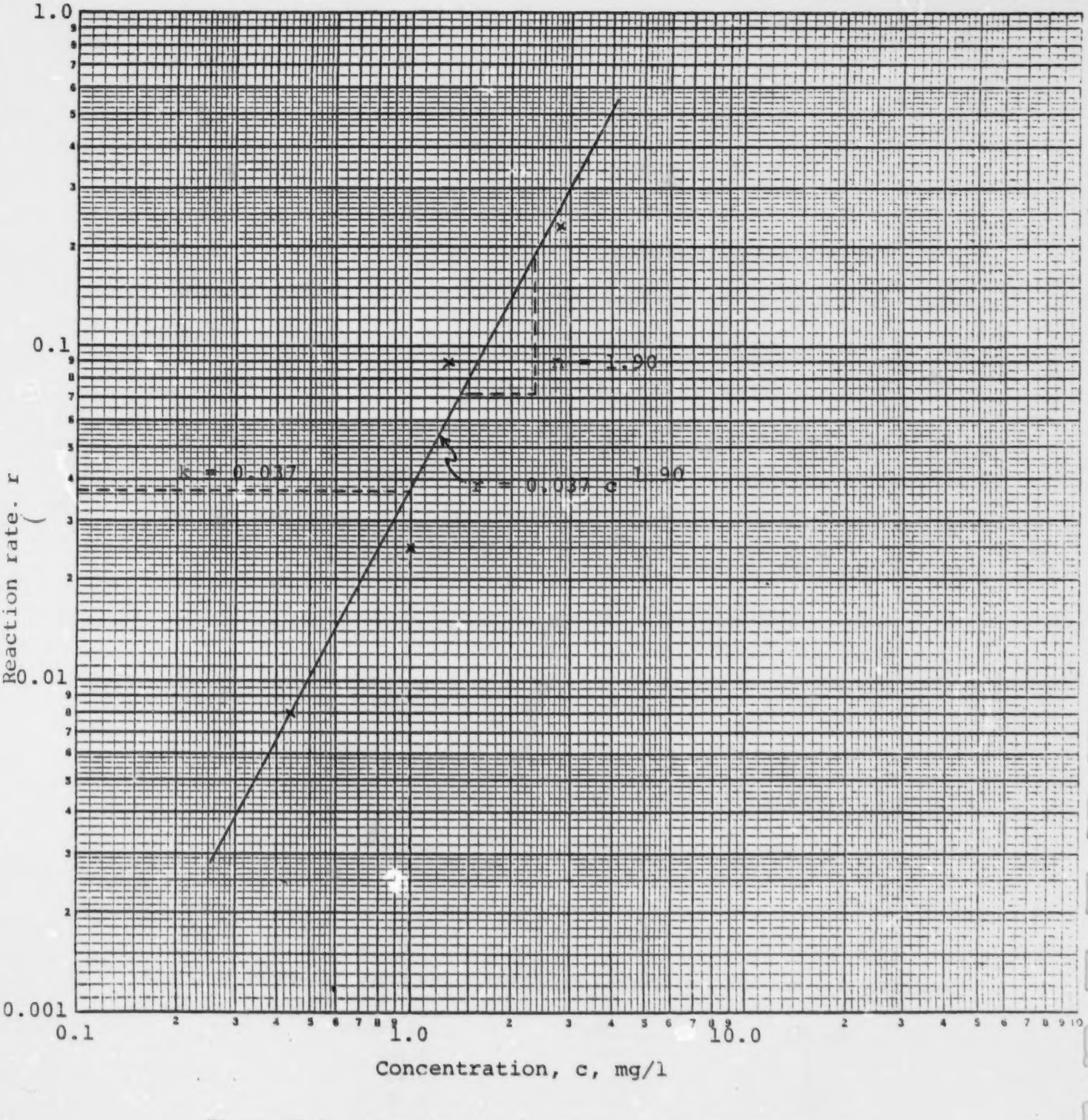


Figure II-3. Determination of Reaction Order for Hydrocarbons

The equation is on the high side in the lower range of time and is a little high for larger times.

Using equation II-5 as a general equation, the results from treatability studies can be expressed in terms of three parameters, initial concentration, c_o, the reaction order, n, and the reaction coefficient, k. Admittedly, equation II-5 only applies for a relatively restrictive case of a constant volume, isothermal, completely mixed batch reactor in which all constituents are assumed to react independently. Nevertheless, it is much better than making the potentially unrealistic assumption that first-order kinetics apply.

References

1. American Society of Civil Engineers, "Sewage Treatment Plant Design," Manual of Practice No. 8, ASCE, 1960.

2. Brown, C.B., "The Control of Reservoir Silting," Misc. Pub. 521, U.S. Department of Agriculture, Washington, D.C., 1943.

3. Brune, G.M., "Trap Efficiency of Reservoirs," Trans. American Geophysical Union, Vol. 34, No. 3, 1953, pp. 407-418.

4. Butt, J.B., Reaction Kinetics and Reactor Design, Prentice-Hall, Englewood Cliff, New Jersey, 1980.

5. Camp, T.R., "Sedimentation and the Design of Settling Tanks," Proc. American Society of Civil Engineers, Vol. 111, 1946, pp. 895-936.

6. Chen, C., "Design of Sediment Retention Basins," Proc. of the National Symposium on Urban Hydrology and Sediment Control, University of Kentucky, Lexington, Kentucky, July 28-31, 1975.

7. Churchill, M.A., "Analysis and Use of Reservoir Sedimentation Data" by L.C. Gottschalk, Proc. Federal Inter-Agency Sedimentation Conference, Washington, D.C., 1948.

8. Consoer, Townsend, and Associates for the City of Milwaukee, Wisconsin, "Detention Tank for Combined Sewer Overflow - Milwaukee, Wisconsin, Demonstration Project," EPA-600/2-75-071, U.S. Environmental Protection Agency, December 1975.

9. Drehwing, F.J. et al., "Combined Sewer Overflow Abatement Program, Rochester, N.Y. - Volume II. Pilot Plant Evaluations," EPA-600/2-79-031b, U.S. Environmental Protection Agency, Cincinnati, Ohio, July 1979.

10. Fair, M.F., Geyer, J.C., and Okun, D.A., Water And Wastewater Engineering, John Wiley and Sons, Inc., New York, New York, 1968.

11. Heaney, J.P. et al., "Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges: Volume II, Cost Assessment," EPA-600/2-77-064, U.S. Environmental Protection Agency, Cincinnati, Ohio, March 1977.

12. Hill, C.G., An Introduction to Chemical Engineering Kinetics and Reactor Design, John Wiley and Sons, Inc., New York, New York, 1977.

13. Holland, C.D., and R.G. Anthony, Fundamentals of Chemical Reaction Engineering, Prentice-Hall, Englewood Cliffs, New Jersey 1979.

14. Howard, C.D.D., Flatt, P.E., and Shamir, U., "Storm and Combined Sewer Storage Treatment Theory Compared to Computer Simulation", Grant No. R-805019, U.S. Environmental Protection Agency, Cinncinati, Ohio, October 1979.

15. Huber, W.C., Heaney, J.P., Nix, S.J., Dickinson, R.E., and Polmann, D.J., "Stormwater Management Model User's Manual—Version III", Project No. CR-805664, U.S. Environmental Protection Agency, Cincinnati, Ohio, November 1981.

16. Hydrologic Engineering Center, Corps of Engineers, "Urban Stormwater Runoff: STORM," Generalized Computer Program 723-S8-L2520, Hydrologic Engineering Center, Corps of Engineers, Davis, California, August 1977.

17. Hydroscience, Inc., "A Statistical Method for the Assessment of Urban Stormwater," EPA-440/3-79-023, U.S. Environmental Protection Agency, Washington, D.C., May 1979.

18. Imhoff, K. and Fair, G.M., Sewage Treatment, John Wiley and Sons, Inc., New York, 1941.

19. Kamedulski, G.E. and McCuen, R.H.. "Evaluation of Alternative Stormwater Detention Policies," Journal of the Water Resources Planning and Management Division, ASCE, Vol. 105, No. WR2, September 1979, pp. 171-186.

20. Lager, J.A. et al., "Urban Stormwater Management and Technology: Update and Users' Guide," EPA-600/8-77-014, U.S. Environmental Protection Agency, Cincinnati, Ohio, September 1977.

21. Levenspiel, O., Chemical Reaction Engineering, Second Edition, John Wiley and Sons, Inc., New York, New York, 1972.

22. Medina, M.A., "Interaction of Urban Stormwater Runoff, Control Measures and Receiving Water Response," Ph.D. Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida, 1976.

23. Nix, S.J., Heaney, J.P., and Huber, W.C., "Water Quality Benefits of Detention", Chapter 12 of "Urban Stormwater Management", Special Report No. 49, American Public Works Association, Chicago, Illinois, 1981.

24. Rich, L.G., Environmental Systems Engineering, McGraw Hill, Inc., New York, 1973.

25. Small, M.J. and DiToro, D.M., "Stormwater Treatment Systems," Journal of the Environmental Engineering Division, ASCE, Vol. 105, No. EE3, June 1979, pp. 557-569.

26. Smith, R., "Preliminary Design and Simulation of Conventional Waste Renovation Systems Using the Digital Computer," Report No. WP-20-9, U.S. Department of the Interior, Federal Water Pollution Control Administration, Cincinnati, Ohio, March 1968.

27. Viessman, W., Jr., Knapp, J.W., Lewis, G.L., and Harbaugh, T.E., Introduction to Hydrology, 2nd edition., IEP, New York, New York, 1977.

28. Ward, A.J., Haan, C.T., and Barfield, B.J., "Simulation of the Sedimentology of Sediment Detention Basins," Research Report No. 103, University of Kentucky, Water Resources Research Institute, Lexington, Kentucky, June 1977.

29. Whipple, W., and J.V. Hunter, "Settleability of Urban Runoff Pollution", Water Resources Research Institute, Rutgers U., New Brunswick, New Jersey, 1980.

Addendum I - Review of Basin Data - Met. Washington, D.C. COG

The use of event quantity and quality data for two basins in the Washington, D.C. area for the purposes of estimating basin performance proved fruitless. A quick review of the data reveals a lack of any relationship between inflow and outflow events. In many cases, the outflow volume is greater than the inflow volume. This is possible only if flows from earlier storms are also being released. Without more knowledge of the operation of these basins, a statement about performance is impossible. However, it may be possible to use these data, with complete knowledge of the basin design and operation, to calibrate a simulator such as the SWMM Storage/Treatment Block.

APPENDIX D

WET WEATHER WATER QUALITY CRITERIA

APPENDIX D
WATER QUALITY CRITERIA FOR URBAN RUNOFF

The section that follows provides the information and methods developed to date for the selection of receiving water quality criteria appropriate for urban runoff. The issue here centers around the difference between the exposure regime used in toxicity tests to develop general water quality criteria (48 to 96 hours or longer) and the exposure regime organisms inhabiting runoff receiving waters could encounter (4.5 to 15 hours). The criteria based on 48 or 96 hour toxicity tests are postulated to be overly restrictive for urban runoff exposures. For the priority pollutants, the EPA published criteria are described; the limitations of the EPA criteria for urban runoff are discussed; and methods to adjust the EPA criteria for short-term urban runoff exposures are presented. Dissolved oxygen and suspended solids criteria are also considered.

PRIORITY POLLUTANTS CRITERIA

EPA Criteria.

In developing the proposed priority pollutant criteria, EPA performed three steps as follows: (1) guidelines were established for use in deriving the criteria, (2) criteria were computed for the protection of human health and aquatic life, and (3) a two-value criterion for each substance was considered for protection of aquatic life. The two values are a maximum, which protects against acute toxicity, and a 24-hour average, which protects against chronic toxicity.

Using their guidelines, EPA derived and published (in three issues of the Federal Register, the last being 28 November 1980) aquatic life and human health criteria for all of the priority pollutants. Criticism of the guidelines resulted in the development of a second set of guidelines which, unlike the first set, specified certain minimum data requirements for deriving aquatic life criteria. These minimum requirements severly limited the number of substances for which criteria could be developed. Hence, although criteria documents were published for all of the priority pollutants, aquatic life criteria were developed for only 20 of them. These are arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, aldrin, chlordane, cyanide, DDT and metabolites, dieldrin, endrin, heptachlor, lindane, polychlorinated biphenyls, and toxaphene.

To obtain the final acute value for protection of aquatic life the following procedure based on LC50 concentrations was used. Note that a LC50 is defined as the concentration that will kill 50 percent of the exposed population of organisms during a specific period of time.

1. The geometric means of LC50 toxicity tests for a pollutant were computed by species. The 48 hour exposure time was taken as

the end-point of the test for most invertebrates and 96 hours for fish and some invertebrates.

2. LC50's for the species were numerically ranked and the numbers transformed to cumulative probability values.

3. A least square regression line, defining the relationship between species-probability values and the mean LC50s was computed.

4. The mean LC50 corresponding to a probability of .05 was identified by interpolation or extrapolation.

The mean LC50 corresponding to a species probability of .05 was defined as the maximum criterion value. Computed in this fashion, the maximum value corresponds to the concentration above which lie the LC50s of 95 percent of the tested species. For pollutants whose toxicity was determined to be affected by some natural property of water, the final acute equation was specified as the means for computing the maximum criterion value. Hardness was the only natural property of water considered.

The final chronic values were computed by much the same method as described above; however, the important differences are:

1. The exposure times for chronic tests were at least 28 days.

2. The test end-point was not the LC50 concentration; rather the concentration values were the geometric means of the lowest tested concentration that caused a statistically significant adverse effect and the concentration immediately below it in the test series were used. When there were insufficient data to compute a final chronic value from chronic data alone, the final acute-chronic ratio (defined as the ratio between the LC50 and final chronic value) was employed.

Generally, the 24 hour average criterion corresponded to the final chronic value. In some cases, however, a final residue value, designed to prevent unacceptable tissue concentrations of pollutants determined the appropriate 24-hour criterion.

Application of the EPA Criteria to Urban Runoff.
A limitation of the EPA criteria centers around differences in the exposure regimen commonly used in toxicity tests (data from which the criteria were derived) and the exposure regimen that organisms inhabiting runoff receiving streams could encounter.

The temporal features of urban runoff events consist of relatively short duration exposures with relatively large time periods between episodes. For sites located in much of the eastern portion of the country, rainstorm statistics (or average) are as follows:

	Storm Duration (hours)	Time Between Storm Midpoints (hours)
Median (50 percentile)	4.5	60
Mean	6.0	80
90 percentile	15.0	200

For the semi-arid region of the western part of the country, storm durations are generally the same as for the eastern U.S., but the period between storms is about twice as long. Runoff discharge times are somewhat longer but generally similar to storm duration times.

The above characteristic time scales are very different from those considered in developing the EPA water quality criteria. Therefore, a question exists as to: what are appropriate water quality criteria for highly time variable discharges such as urban runoff? That is, are the EPA criteria overly restrictive for urban runoff exposures?

It is well known that with the kinds of biological responses measured in toxicity tests (with aquatic organisms), the concentration of a chemical substance required to elicit a response of a given magnitude, be it some percentage of mortality, reduction in growth rate, reduction in fecundity, etc., is usually inversely proportional to the time of exposure. For the priority pollutants, data used to derive the maximum criterion value were chosen only from 48- and 96-hour tests. Data used to derive the 24-hour average criterion value were chosen from tests with exposure times of at least 28 days.

Because the duration of storms is much shorter than the exposure times used in toxicity tests, it is quite likely that use of the criteria to assess the hazard of urban runoff will overestimate the hazard.

Time is not the only factor of difference. In toxicity tests, the test organisms are exposed to constant concentrations and exposure is continuous throughout the test. In urban runoff receiving waters, the concentrations of potentially toxic constituents change continuously during events as well as from event to event. Runoff events are episodic, occurring on the average of every 60 hours. Although repeated exposure to chemical substances in the runoff could cause chronic effects in organisms, little is known about the effects of such repeated exposures. The occurence of adverse effects probably is greater when exposure to a given concentration is continuous rather than intermittent.

The maximum criteria values proposed by EPA are LC50s (EPA used 48 and 96 hour LC50s). Because of differences in individual sensitivity, it is not necessarily true that a population must be exposed to a 48 or 96 hour LC50 for 48 or 96 hours for 50 percent mortality to occur. Figure 1a, b and c show a set of hypothetical time-mortality curves for populations exposed to a 96-hour LC50 of a chemical.

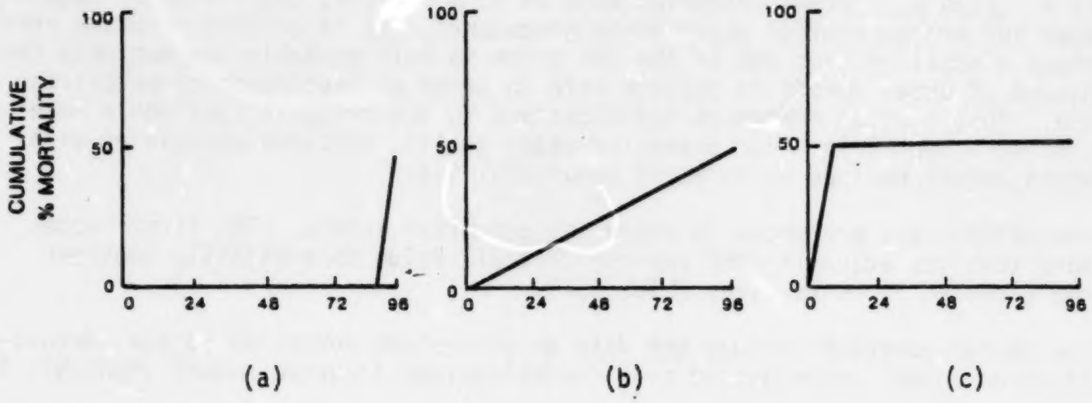


Figure 1. Time Mortality Curves

Figure 1a represents a case where only during the last few hours of the test does any mortality occur. During those hours, 50 percent of the organisms die. Such a time-mortality pattern is extremely rare. Figure 1b illustrates a case where mortality occurs gradually and reaches 50 percent around the 96th hour. Figure 1c shows a case where 50 percent of the population dies during the first 24 hours. Figures 1b and 1c represent the most commonly observed kinds of time-mortality patterns and indicate that exceedance of a maximum criterion value for very short periods could cause death or adverse sublethal effects in some sensitive species. These types of responses partially illustrate the complexity of the situation. The procedure presented below could be used to differentiate these types of responses and provide information directly usable to assess the impacts of urban runoff.

The runoff discharge duration may not always be an accurate measure of exposure time. In some instances, exposure time can be much longer than the storm duration. Certain kinds of organisms could be exposed to runoff constituents long after discharge ceases. Such organisms include phytoplankton and zooplankton (including fish eggs and larvae), each of which could become entrained in the runoff plume. The net effect is that a percentage of certain populations may experience longer exposure times.

Even for situations where the organism exposure time is longer than the actual discharge period, the differences in exposure regime for organisms in runoff receiving waters and for organisms in toxicity tests are very large. For example, to derive the 24 hour average criterion values, an exposure time of at least 28 days was used. It is quite possible that for urban runoff, a 24-hour criterion value is not appropriate. For the same reasons, the proposed maximum criterion values may also be inappropriate for urban runoff. For the NURP project, procedures to explicitly consider the short duration exposures characteristic of urban runoff were investigated as described below.

Impairment of Beneficial Use Criteria.

Impairment of beneficial use will, for the following discussion, be considered concentrations that result in mortality of 50 percent of the population (i.e., LC50's). Other criteria, such as no mortality, could also be developed and employ similar calculation procedures. It is evident from the previous discussion that use of the EPA criteria will probably overestimate the hazard of urban runoff to aquatic life in terms of impairment of beneficial use. This section addresses modifications to the criteria that would make them more appropriate for assessing water quality problems associated with urban runoff defined in terms of beneficial use.

Two methods are presented to establish criterion levels. The first procedure involves adjusting the maximum criteria value to explicitly consider the expected exposure times (LIU, 1979).

The second approach employs the data on equivalent mortality dosage, detoxification rates, and expected mean concentrations in urban runoff (MANCINI, 1982).

The first procedure adjusts the maximum criterion values so that they relate more closely to expected exposure times in runoff receiving streams. This entails computing a value that when divided into the maximum criterion value of a pollutant will provide an estimate of the LC50 corresponding to the exposure time of interest. This LC50 is called the time-adjusted LC50, and is computed as described below. The assumption is that meeting the adjusted criteria for intermittent exposures, provides the same degree of protection implied by the base criteria value, that is, that a generally healthy aquatic life population will be maintained.

A set of factors for converting 24-, 48-, and 72-hour LC50's to 96-hour LC50's were presented in the 18 May 1979 issue of the Federal Register (40 FR 21506). The factors are 0.66, 0.81, and 0.92 and are the respective geometric means of all 96:24, 96:48, and 96:72 hour LC50 ratios computed for individual chemicals on a test-by-test basis using LC50 estimates available at that time. The relationship between the 24, 48, and 72 hour exposure times and the factors for converting the LC50's associated with these exposure times to 96-hour LC50's is described by the linear equation:

$$y = (0.563 \log_{10} \chi) - 0.123. \qquad (1)$$

Where χ is the exposure time in hours and y^{-1} is the 96:x LC50 ratio. The correlation coefficient for this relationship is 0.998.

To extend the range below 24 hours, geometric means of the 96:1, 96:2, 96:4, 96:8, and 96:16 hour LC50 ratios were computed using experimental 1, 2, 4, 8 and 16 hour LC50 estimates for 10 chemicals (June, 1979). These short exposure means and the above values obtained by EPA were included in a least squares regression. The analysis indicated that the relationship can be described by the linear equation:

$$y = (0.35 \log_{10} \chi) + 0.27 \qquad (2)$$

The correlation coefficient for this relationship is 0.994. Clearly, Equation (2) can be used to convert a LC50 for an exposure time less than 96 hours to the 96 hour LC50 value, or to convert a 96 hour LC50 to a LC50 for a smaller exposure time.

Equation (2) was used to convert 96 hour LC50's obtained by Liu for the 10 chemicals considered to LC50's for exposure times of 1, 2, 4, 8, and 16 hours. The computed short exposure LC50's were compared to measured values with reasonably good agreement.

The time-adjusted maximum criterion value (CV_t) is computed from the maximum criterion value (MCV) using the equation:

$$CV_t = \frac{MCV}{y} \tag{3}$$

Applying the conversion method to the maximum criterion value instead of to some specific 96-hour LC50 is valid because the maximum criterion value could be considered a 96-hour LC50. It was derived from 48-hour LC50's from tests with certain invertebrates and 96-hour LC50's from tests with fish and certain invertebrates. The 48- and 96-hour LC50's were considered equivalent end-points. As indicated by Equation (3), the adjustment ratio y is assumed to be the same for all chemicals.

Table 1 presents the maximum criterion values and time-adjusted criterion values for all of the priority pollutants for which maximum criterion values are available. The time-adjusted values correspond to exposure times of 4.5, 6.0, 15 hours, which for at least the eastern portion of U.S. are the median, mean, and 90th percentile duration of storms.

The second approach which has been used to estimate concentration levels against which intermittent exposure concentrations due to urban runoff can be compared, and employs data on equivalent mortality dosage, detoxification rates, and mean concentrations in urban runoff.

The framework considers uptake and depuration of toxics by organisms and calculates an equivalent toxic dosage. The calculation results provide a method of obtaining a dose response relationship for organisms which are subjected to time variable toxic concentrations. The framework employs data collected from standard bioassay test procedures to evaluate the coefficients required in the analysis. The procedures have been tested under four sets of conditions which employed constant concentration bioassay results to predict organism mortality as a result of exposure to time variable concentrations.

A series of calculations were developed which considered exposure of the more sensitive fish (in a limited data base that had been analyzed) to a series of average duration storm events having the mean concentration of each contaminant. The interval between storms was 60 hours (the median). The calculated equivalent dosage was allowed to stabilize, and the concentration required to produce mortality at the 50 percent level of population sensitivity was calculated. The results are summarized in Table 2. These results include the effects of carryover between average storm conditions. The calculated concentrations for mortality are presented for 4.5 and 12-hour duration storms (the 50 and 85 percentile, respectively).

While the concentrations provided by the first procedure are essentially estimates of "safe" levels, those provided by the second procedure provide estimates of intermittent concentration levels which would result in a serious

TABLE 1. MAXIMUM AND TIME-ADJUSTED CRITERION VALUES FOR SELECTED PRIORITY POLLUTANTS

POLLUTANT	EPA MAXIMUM CRITERION VALUES (μg/ℓ)[1],[2]	TIME-ADJUSTED MAXIMUM CRITERION VALUES (μg/ℓ)		
		4.5 HOURS	6.0 HOURS	15 HOURS
Arsenic	440	880	810	650
Cadmium	3.0	6	5.5	4.4
Chromium (+3)	4,700	9,400	8,650	6,900
Chromium (+6)	21	42	39	31
Copper	22	44	40	32
Lead	170	340	313	250
Mercury	4.1	8.4	7.7	6.2
Nickel	1,800	3,600	3,300	2,650
Selenium (Selenite)	260	520	480	380
Silver	4.1	8.2	7.5	6.0
Zinc	320	640	590	470
Aldrin	3.0	6.0	5.5	4.4
Chlordane	2.4	4.8	4.4	3.5
Cyanide	52.0	104	96	76
DDT (p,p)	1.1	2.2	2.0	1.6
Dieldrin	2.5	5.0	4.6	3.7
Endrin	0.18	0.36	0.33	0.26
Heptachlor	0.52	1.04	0.96	0.76
Lindane (gamma HCB)	2.0	4.0	3.7	2.9
Toxaphene	1.6	3.2	2.9	2.4

[1] Values specified for "total recoverable" metals

[2] Values based on a hardness of 100 mg/ℓ as $CaCO_3$

TABLE 2. CALCULATED CONCENTRATIONS REQUIRED FOR MORTALITY OF SOME FISH SPECIES AS A RESULT OF EXPOSURE TO URBAN RUNOFF

Chemical	Event Mean Concentration(1) µg/ℓ Urban Runoff	Concentration (µg/ℓ) for 50% Mortality(2) Urban Runoff Storm 4.5 HR	12 HR
Zinc	160	1800	800
Copper	30	600	200
Lead	330	11,000	4300
Cadmium	3	11	5

NOTES: (1) Event mean concentration was not obtained from the NURP data base.

(2) Effects of carry-over of expected mean concentrations and other average storm conditions are included.

adverse impact (50 percent kill of the selected species). The assumption utilized in the screening calculations which evaluate impact levels, is that such events, while they would, constitute a severe insult to the biological population, would not totally deny that use if they were to recur at sufficiently infrequent intervals.

A comparison of the "safe" concentrations in Table 1 and the calculated concentrations for 50 percent mortality in Table 2 indicate that there are substantial differences. In addition to the fact that they represent different levels of effect, these differences are in part a result of the differences in data base used to define sensitive species. Another equally important source of this difference, is the manner in which the duration of exposure has been included in the analysis.

Neither set of concentrations are completely satisfactory criteria for storm event related exposures. The published criteria do not explicitly account for the time scale of exposures associated with storm events. These criteria tend to be over protective of the environment by restricting allowable concentrations during the short exposure periods characteristic of runoff events. By contrast, the adjusted criteria presented in Tables 1 and 2 tend to overestimate allowable concentrations since the data base analyzed may not include representative sensitive species which require protection.

Assuming little or no exposure under non-storm ambient conditions, concentration criteria which are appropriate for storm related phenomena would be between the two sets of values. Methods have been developed which would employ the existing data base to calculate criteria which consider time variable concentrations and exposure periods which are consistent with storm event exposure durations and the interval between storms.

Chronic Effects

The usual approach to establishment of water quality criteria considers acute effects such as mortality and chronic effects such as inhibited reproduction, etc.

The EPA criteria derive the maximum value from acute effects protection limits and the 24-hour value from chronic effects protection limits (as derived by an acute/chronic ratio times the maximum). A method is available to calculate the time history of stress on the organism ("equivalent exposure"). The equivalent mortality dose producing mortality of 50 percent of the population is obtained from the analysis of bioassay data. The calculated equivalent dose at any time which results from some sequence of exposures can be divided by the equivalent mortality dose. This ratio (as % of equivalent mortality dose) could be considered as a measure of the chronic stress to which the organism is subjected.

Table 3 presents the calculated percent equivalent mortality dose carried over (on average) from a sequence of storms. This is the calculated equivalent mortality dose at the start of a storm event. Table 3 also presents information on the calculated percent equivalent mortality dose at the end of 4.5 and 23 hour storms whose concentrations are at the mean expected value. These results suggest that, for some of the toxics analyzed, a variable but moderately high level of stress may result from exposure to the undiluted contaminants in urban runoff. Stresses on the order of 2 to 25 percent of the equivalent mortality dose could produce some chronic effects (and possibly some acute effects as well). The calculations presented in Table 3 are for undiluted urban runoff. Computations could be developed considering various dilutions of the runoff.

TABLE 3. CARRYOVER EFFECTS BETWEEN URBAN RUNOFF STORMS

Chemical	Expected Mean Concentration (mg/ℓ)	% Mortality Stress		
		Average Carryover	@ 4.5 hr. Storm	@ 12 hr. Storm
Zinc	.163	8.6	15.7	26.8
Arsenic	.05	-	-	-
Copper	.03	2.6	6.4	12.2
Lead	.325	8.3	8.8	9.7
Chromium	.018	-	-	-
Cadmium	.003	2.3	3.1	4.4

Dissolved Oxygen Criteria.

Water quality criteria for dissolved oxygen (D.O.), which are specifically designed for exposures associated with urban runoff, have not been examined in detail. EPA promulgated criteria set a minimum D.O. of 5 mg/ℓ. D.O. standards such as those proposed by the State of Ohio (Federal Register Vol. 45, 231, 11/28/80, 79054) for warm water fisheries on some water bodies specifying 5 mg/ℓ for 16 hours of any 24 hour period and not less than 4 mg/ℓ at any time were denied by EPA. There is strong historical precedence for maintaining D.O. standards on most water bodies at a minimum of 5 mg/ℓ. This is usually based on information similar to that summarized in Table 4.

An approach to dissolved oxygen water quality criteria similar to that used for priority pollutants can be considered. Based on the information summarized in Table 4, criteria for D.O. during storm event time scales could be set at 2.5 mg/ℓ.

TABLE 4. SUMMARY OF THE INFORMATION AVAILABLE ON THE EFFECTS OF DISSOLVED OXYGEN CONCENTRATION ON FISH

Dissolved Oxygen	Effects Reported	Reference
Saturation to 5 mg/ℓ	1. Generally considered adequate for a healty population.	USEPA (7)
5 mg/ℓ to 2.5 mg/ℓ	1. Sublethal effects on adults observed in laboratories.	(Abernathy) (28)
	2. Reduced growth rate associated with constant exposure of adults.	(Siefert et al.) (29) (Moss) (26) (Warren) (30)
	3. Some increased mortality of early life stages (no direct data on population effects).	
	4. Time variable exposures (8 to 12 hours every 24 hours) appeared to result in reduced growth rates.	(Whiteworth) (31)
2.5 mg/ℓ to 1.5 mg/ℓ	1. Possible mortality of adult and/or smaller fish due to combination of stresses with significant D.O. contribution to mortality.	(Moss) (26) (Abernathy) (28) (Warren) (30)
1.5 mg/ℓ to zero	1. Fish mortality (short exposure).	(Moss) (26) (Warren) (30)

Total Suspended Solids Criteria.

The link between total suspended solids (TSS) concentrations and impairment of beneficial use is not well defined. Except at very high levels, the primary aquatic life effects of TSS are indirect. These include such problems as benthic impacts due to deposition and scour which cause habitat damage, especially in areas subject to lower stream flow velocities. To estimate some measure of TSS levels for urban runoff, the findings of a 1965 study of suspended solids effect by the European Inland Fisheries Advisory Commission was adopted.

The Commission's study resulted in the following conclusions relating to inert solids concentrations and satisfactory water quality for fish life:

1. There is no evidence that concentrations of suspended solids less than 25 mg/ℓ have any harmful effects on fisheries.
2. It should usually be possible to maintain good or moderate fisheries in waters which normally contain 25 to 80 mg/ℓ suspended solids. Other factors being equal, however, the yield of fish from such waters might be somewhat lower than with less than 25 mg/ℓ.
3. Waters normally containing from 80 to 400 mg/ℓ suspended solids are unlikely to support good freshwater fisheries, although fisheries may sometimes be found at the lower concentrations within this range.
4. At best, only poor fisheries are likely to be found in waters which normally contain more than 400 mg/ℓ suspended solids.

The Commission report also stated that exposure to several thousand mg/ℓ for several hours or days may not kill fish and that other inert or organic solids may be substantially more toxic.

Summary of the Criteria Used.

There are clearly limitations and problems with the various criteria as discussed above. Considering this situation, the NURP project has adopted a number of criteria for use in the study. The EPA criterion values for priority pollutants were employed to represent water quality problems defined in terms of numerical standards. In addition, values based on the results of the procedures to establish criterion which explicitly consider the short-term exposures of urban runoff were selected to represent water quality problems defined in terms of beneficial use protection.

For beneficial use protection, two numerical criterion values representing "effects levels" were selected - one for mortality at approximately the 50 percent level of population sensitivity and a second which is the 50 percent mortality value reduced by a factor of two. This second value was taken to represent no substantial mortality which would effect the overall population and therefore beneficial water usage.

A summary of the water quality criterion values used in the screening analyses performed by NURP is presented in Table 5. For the heavy metals, the EPA criteria are specified for "total recoverable metals." The effects level criteria were developed from bioassay data in which the tests used soluble salts of the metal. The criteria thus reflect only the toxic species of the heavy metals. In applying these criteria, the solids content of the runoff and the tendency for metals and other priority pollutants to absorb to this material must be considered.

TABLE 5. SUMMARY OF WATER QUALITY CRITERION VALUES USED IN NURP STUDY
CONCENTRATIONS - μg/ℓ

CONTAMINANT	EPA CRITERIA[1]		EFFECTS LEVELS[2]	
	24 HOUR	MAX	ESTIMATED THRESHOLD[5]	50% MORTALITY[6]
Zinc	47	320	600	1,600
Chromium (Total)	(40)[3]	4,700	8,650	—
Copper	5.6	22	40	500
Lead	3.8	170	313	4,500
Cadmium	.025	3	5.[5]	10
Arsenic	(40)[3]	440	810	—
TSS[4]	25	250	2,500	
BOD[4]	5	15	50	

[1] Based on a hardness of 100 mg/ℓ as $CaCO_3$.

[2] Hardness not explicitly considered, but values developed from data in relatively soft water.

[3] No criteria proposed - value shown is lowest observed chrome concentration reported in EPA documents.

[4] No criteria for these pollutants - values shown represent levels estimated to represent equivalent criteria effects (for use in screening analysis activities).

[5] Based on Procedure #1 estimates of "safe" levels for intermittent exposures (average duration 6 hr).

[6] Based on Procedure #2 estimates of serious impact from intermittent exposures (average duration 6 hr).

REFERENCES

Liu D. H. W., H. C. Carley, B. E. Suta, Static, Flow Through and Plug Flow Bioassay Study with the Bluegill Sunfish Exposed to 10 Chemical Toxicants, by SRI International, For EPA, contract 68-01-4108, 1979.

European Inland Fisheries Commission. "Water Quality Criteria for European Freshwater Fish Report on Finely Divided Solids and Inland Fisheries." International Journal of Air and Water Pollution, Vol. 9. 1965.

Mancini, J. L. "Development of Methods to Define Water Quality Effects of Urban Runoff;" EPA Cooperative Agreement No. 806828, (1982, in press).

C3

APPENDIX E

INDIVIDUAL PROJECT SUMMARIES

Appendix E

Summaries of conclusions for selected NURP projects are presented in this appendix. The projects are presented in order by EPA Region number from I through X as follows:

Region I	Lake Quinsigamond, MA Durham, NH
Region II	Irondequoit Bay, NY Long Island, NY
Region III	Baltimore, MD
Region IV	Winston-Salem, NC
Region V	Lansing, MI Ann Arbor, MI Oakland County, MI Glenn Ellyn, IL Champaign, IL Milwaukee, WI
Region VI	Little Rock, AK Austin, TX
Region VIII	Denver, CO
Region IX	Castro Valley, CA
Region X	Bellevue, WA

NATIONWIDE URBAN RUNOFF PROGRAM

MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING

LAKE QUINSIGAMOND, MA

REGION I, EPA

Lake Quinsigamond NURP.

A major component of the work plan for the Lake Quinsigamond NURP project was to evaluate the response of the receiving water to stormwater inputs. A detailed evaluation of the response of Lake Quinsigamond and Flint Pond to pollutant loadings was conducted. The evaluation was based on intensive lake and tributary monitoring data collected under the 314 Clean Lakes Diagnostic study, together with tributary and stormwater sampling data collected by the NURP project. The analysis utilized a batch phosphorus model to simulate the most important interactions affecting dissolved oxygen and algal populations in the lake. Based on this analysis, the major findings can be summarized as follows:

- Water quality conditions in Lake Quinsigamond and Flint Pond have remained relatively stable between 1971 and 1980. This can be largely attributed to the lake's morphology and self-limiting chemical characteristics.

- Chlorophyll, transparency, and hypolimnetic oxygen depletion rated indicate that Lake Quinsigamond is in a late mesotrophic stage. Despite its similar water quality conditions, Flint Pond is classified as eutrophic due to its aquatic weed densities. The differences between Lake Quinsigamond and Flint Pond can be attributed to differences in morphological characteristics.

- Major water quality problems identified in the lake include hypolimnetic oxygen depletion, heavy metals build-up in sediments, near-shore solids deposition, and tributary bacterial levels. Reduction of cold-water fisheries habitat is the major use-related impairment identified in the lake. Bacterial levels in the tributaries have resulted in the closing of one secondary water supply well (Coalmine Brook). It is important to note that, in this case, urban runoff is not, per se, the source of the problem. Misconnections, leaky sewers, and direct discharges have been identified as the primary source of this problem.

- Excessive weed growth and heavy metals in sediments have been identified as the major water quality problems in Flint Pond. These have resulted in significant impairment of recreational use of the pond in terms of swimming, boating and fishing.

- Dissolved phosphorus has been identified as the major limiting nutrient and most important from a control standpoint. Lake mass balances and literature studies suggest that between 0 and 20 percent of the particulate phosphorus loads entering the lake are eventually able to support algal growth.

- Nutrient balance calculations indicate that surface runoff accounts for 87 percent of the total phosphorus, 67 percent of the dissolved phosphorus, 96 percent of the suspended solids, and 49 percent of the total nitrogen input to the lakes. Tributary base flow and atmospheric inputs account for the remaining loadings. Dissolved phosphorus inputs to Flint Pond from unsewered areas is nominally estimated at 18 percent.

Lake Quinsigamond (Cont'd)

- Analysis of lake data in relation to antecedent rainfall periods indicate significantly higher concentrations of total phosphorus, dissolved phosphorus, and coliform bacteria on wet days as compared with dry days. More intensive sampling is required to more adequately assess the extent and significance of short-term bacterial standards violations in specific areas of the lake.

- Future land uses are estimated to result in a 12-14 percent degradation in average water quality conditions, as measured by suspended solids, available phosphorus, and other eutrophication-related variables. Therefore, control of 12-14 percent of future available phosphorus and suspended solids loadings would be needed to maintain existing water quality.

- Reduction of phosphorus loadings to insure 200 days of hypolimnetic oxygen supply at spring turnover is suggested as a potential water quality management objective. This would reduce the potential for internal metals and nutrient cycling, improve fish habitat, and provide proportionate reductions in chlorophyll and increases in transparency.

- Under projected future land uses, the above objective would require about a 50 percent reduction in loadings of available phosphorus in surface runoff during an average hydrologic year. Control requirements during a wet hydrologic year would be more stringent (78%).

- Because of the importance of dissolved phosphorus loadings, watershed management strategies for reducing runoff volumes by encouraging water infiltration should be examined along with runoff treatment schemes as means of achieving water quality objectives.

Based on the findings enumerated above, a comprehensive water quality management plan is being developed of which the urban runoff component is a major element. Watershed management plans are being developed for each major tributary. Natural detention/storage mechanisms are being utilized as in-system filters for solids and nutrient controls to the maximum extent possible. Wherever possible, groundwater recharge options for stormwater are being considered. End-of-pipe and inline solids treatment systems are being considered for major stormwater systems discharging directly to the lake (e.g., Route 9 drain, medical school drain, I-290 drainage system). Combinations of Best Management Practices, including street-sweeping and catch basin-cleaning, among others, are also being considered as appropriate in developing an overall stormwater management strategy for the watershed.

Finally, it is extremely important to recognize that stormwater management is one component of the water quality management plan under development. Other major components of this program are the control of sanitary sewage discharges via leaks, misconnections and other sources, and septic system leachate inputs from unsewered areas.

NATIONWIDE URBAN RUNOFF PROGRAM

NEW HAMPSHIRE WATER SUPPLY AND
POLLUTION CONTROL COMMISION

DURHAM, NH

REGION I, EPA

Durham, New Hampshire

Two streams were monitored at stations upstream of the urban area for background conditions, and at downstream locations where the effect of urban runoff could be observed. At one location; the Oyster River, monitoring results from three storm events show no detectable increase in concentrations at downstream stations compared with upstream boundary levels during storms. (Not surprising since "urban area" constitutes only about 6 percent of the contributing catchment, and 1/3 of this is Institutional giving a Drainage Area Ratio of 15.6.) Pette Brook, with 23 percent of the catchment above the downstream monitoring station (DAR 3.3) shows a "trend of increased concentration" observed during storms. Data are insufficient at this time for assessing whether the fishable/swimmable use classification is impaired.

Mass loads discharged into the estuary during storms appear to be significant in magnitude when all sources (urban and non-urban) are considered. The impact of such loads on important downstream water bodies (the estuary), whether a significant effect on beneficial use is probable, and whether the contaminant loads which originate from urban areas are an important contributor to any detrimental effect, have not yet been determined.

Control techniques for reducing urban runoff loads will be evaluated for their ability to control any potential problems that are anticipated and will provide important information for statewide programs.

NATIONWIDE URBAN RUNOFF PROGRAM

NEW YORK STATE DEPARTMENT OF
ENVIRONMENTAL CONSERVATION

IRONDEQUOIT BAY, NY

REGION II, EPA

WATER QUALITY IMPACTS

Irondequoit Bay is the receiving water body for a 153-square-mile watershed in western New York. The Bay is a prime water resource for the urbanized area surrounding the City of Rochester. However, much of the recreational potential of the Bay is restricted by its advanced state of eutrophication. The problems associated with Irondequoit Bay - hypolimnetic oxygen depletion, turbidity, and adverse fishery impacts - all result from the phosphorus-enriched status of the Bay. Local government has implemented a plan to eliminate all point source discharges to the Bay and its watershed. It is the intent of the urban runoff project to examine the role of diffuse urban runoff pollution in the progressive eutrophication of Irondequoit Bay.

Seventy-five percent (75%), or 115 square miles, of the total watershed is being studied under the urban runoff project. The remaining twenty-five percent (25%), or 38 square miles, at the upstream end of the watershed will be part of a rural non-point source assessment study. Preliminary land use figures indicate that the NURP study area contains 36 square miles of residentially developed lands (i.e., 31%), 12 miles square miles of commercial/industrial development (11%) and 67 square miles of parkland/undeveloped land (52%). These figures typify the area which is undergoing intensive suburban development with a major shift from active and inactive agricultural use to residential use.

A scan of the water quality parameters monitored during 1980 shows that the event mean concentrations all fall within the range reported in the USEPA Preliminary Report dated 9/30/81. Detailed loadings from the individual land use monitoring sites and the watershed as a whole are being developed for phosphorous, lead and suspended solids. Preliminary results suggest that 55% of the total phosphorous load comes from the urban study area which comprises 75% of the total watershed area. Conversely, the agricultural area, which comprises only 25% of the land area, produces 45% of the total phosphorous load. The lead loading in the watershed appears to be directly proportional to the land area: the agricultural area produced 25% of the load and the urban area produced 75% of the load. A more detailed breakdown of loadings within the urban study area is underway.

The project is considering several treatment and management options to control urban runoff pollution including detention/retention facilities, street sweeping, porous pavement, and decreased road salting. One of the most promising proposals is to utilize an existing 100-acre wetland located at the south end of the Bay to remove nutrients and suspended solids. If managed properly, this wetland would renovate the runoff from both the urban and rural areas just prior to its entry into the Bay. Monitoring sites have been constructed at the influent and effluent ends of the wetlands and they will provide the basic information necessary for developing a phosphorous budget and estimating sediment loss within the wetland unit. The expected output from this study will include recommendations for developing a demonstration project in the wetland.

NATIONWIDE URBAN RUNOFF PROGRAM

LONG ISLAND REGIONAL PLANNING COMMISSION

LONG ISLAND, NEW YORK

REGION II, EPA

========== ===== ====== =======
NATIONWIDE URBAN RUNOFF PROGRAM
========== ===== ====== =======

Long Island, N.Y.

December 10, 1981

PROJECT SUMMARY

Long Island Regional Planning Board

in cooperation with

U.S. Geological Survey
Nassau County Department of Health
Suffolk County Department of Health Services

174

I. PROJECT LOCATION

The Long Island component of the NURP deals with the urban runoff problems affecting the ground and surface waters of two New York Metropolitan Area Counties: Nassau and Suffolk. The receiving waters of principal interest to the counties of Nassau and Suffolk in the L.I. NURP program are the groundwater reservoir and the south shore marine embayments. The groundwater recharge basin project sites are located at Laurel Hollow, Syosset and Plainview in the Nassau Town of Oyster Bay and at South Huntington and Centereach, in the Suffolk Towns of Huntington and Brookhaven, respectively. The surface water project sites are located at Unqua Pond and Bayville in the Town of Oyster Bay; on the Carll's River in the Town of Babylon; and on Orowoc Creek in the Town of Islip.

II. PROJECT DESCRIPTION

A. Urban Runoff Related Problems

The quantity and quality of available groundwater and the quality of surface waters have long been concerns of Long Island officials and residents, who recognized their dependence on the groundwater for potable supplies and on the surface waters for recreation and for the economically important shellfish industry. The 208 Study, which addressed these concerns, found that stormwater runoff is a major, and in many cases, the major non-point source of pollution in the bi-county region. The 208 investigations indicated that runoff from highways, medium and high density residential areas, and commercial and industrial areas was contributing varying amounts of coliform bacteria, organic chemicals, sediment, heavy metals, and nitrogen to both ground and surface waters.

A question was raised as to whether the more than 3000 recharge basins or sumps used throughout the island as outlets for local drainage systems and as devices for replenishing the aquifers were contributing to the areawide contamination of the drinking water. Did the basins function as conduits facilitating the entry of water borne pollutants or did they function as control devices filtering out some or all of the pollutants?

Stormwater runoff was identified as the major source of bacterial loading to marine waters and, thus, the indirect cause of the denial of certification by the New York State Department of Conservation for about one fourth of the shellfishing area, an area containing an estimated one third of the clams. Much of this area is along the south shore, where the annual commercial shellfish harvest is valued at approximately $17.5 million. Figure 1 shows the location of areas closed to shellfishing as of June 1981. Deep embayments along the north shore provide an important recreational resource and, to a lesser extent, shellfish beds. Runoff-related closure of bathing beaches in response to elevated coliform counts is a minor problem since such incidents tend to be relatively infrequent and of short duration.

B. Legal/Political Implications, Public Attitudes

There are local legal implications of Long Island's runoff problems; however, they do not appear to be as significant as in many areas. Inasmuch as the drainage basins contributing runoff, and the receiving waters, are generally located within the same political jurisdiction there is no question of municipal liability for the diminution of the rights of the downstream user as is often the case in a riverine situation. There is a legally established long term denial of a beneficial use —the taking of shellfish — in portions of the bay in response to the presence of coliform bacteria at levels in excess of the prescribed New York State standard 70mpn/100ml for the certification of shellfishing areas. In addition there is a similar relatively infrequent, short term denial of the beneficial use of certain beaches, based upon the existence of coliform levels that contravene the standards for bathing or contact recreation, 2400mpn/100ml.

The legal implications of the proposed control measures vary from measure to measure. In the case of stream corridor storage and stream bed infiltration legal difficulties appear unlikely so long as the area subject to inundation is not increased beyond the historical limits of the floodplain and so long as groundwater elevations and impoundment levels do not exceed those that prevailed during wet years prior to sewering and the consequent drop in water table elevations.

Any modification of the stream beds to provide stormwater flow to maintain freshwater wetlands or to improve percolation could involve questions of ownership and on occasion the need for temporary or permanent easements.

Police power intervention may be required to protect the beds of streams and ponds that are drying up from the type of encroachment that would impair their usefulness in retaining or detaining runoff.

In the case of pond modifications such as dredging, the construction of weirs, or the installation of baffles to avoid short circuiting and increase detention time, not only the ownership of the bottom, but also the rights of adjacent and nearby residents to recreational use of the waters would have to be considered.

The reliance on land use controls, such as zoning, subdivision regulations and the acquisition of the fee or lesser interests in land in order to preserve or protect stream corridor areas not already dedicated for open space or conservation purposes, raises political and fiscal rather than legal questions. Similarly, changes in drainage system requirements to foster use of the Bayville type leaching system; the prohibition of duck feeding; and the enforcement of existing wetlands protection and dog controls involves problems of costs and public acceptance rather than legal authority.

Both the problems and the proposed controls have political implications. There is political dissatisfaction resulting from the denial of beneficial uses of marine waters. This has been manifested in the growth of baymen's, sportsmen's and conservation organizations that have lobbied for improved water quality in nearshore areas and/or changes in the New York State standards for certification. seeding of open shellfishing areas and habitat creation or restoration.

As for the control measures, there appears to be little or no political opposition to storage and stream bed infiltration and freshwater wetlands preservation. In fact, to the extent that NURP control measures obviate the need for remedial action to offset groundwater losses attributable to sewering, they may generate considerable political support.

There is likely to be moderate to significant opposition to other proposed measures because of the (relatively minor) capital outlays required for pond modifications and the installation of leaching systems, the major capital outlays for the acquisition of lands or development rights, and the potential loss of rateables.

Opposition to the enactment of a ban on the feeding of waterfowl and to the enforcement of dog control and tidal wetlands laws arises not so much from fiscal concerns as from the view that such actions constitute an unwarranted infringement of personal and property rights.

Public attitudes affect both the perception of the problem and the willingness to support mitigating measures. Many Long Island residents have little understanding of causal relationships, particularly in the case of stormwater runoff. Public concerns in respect to recharge basins have focused on issues of safety and appearance rather than water quality. As for marine waters, the attitude has generally been one of annoyance with the inconvenience of beach closures and a tendency to regard them either as the result of an "act of God" or the fault of New York City. Recreational and commercial shellfishermen, although frequently at odds with one another, share a common desire for improvements in water quality and for changes in what they regard as unnecessarily stringent certification requirements.

The need for strong public support for proposed control measures, especially those such as a ban on waterfowl feeding and pooper-scooper laws that must rely on voluntary compliance, indicates the need for a well designed, well-funded public education program.

C. BMP's Investigated

1. Nassau County Department of Health

    a. Natural Impoundment - Unqua Pond, Massapequa

        1) Location: Southest corner of Nassau County, New York

        2) Drainage Area: 298.5 acres, consisting of
        253 acres (85%) medium density residential
        15 acres (5%) commercial
        30 acres (10%) open space

        3) Description: 5.5 acres "natural" impoundment with a depth of 3-5 feet having a baseflow volume of approximately 900,000 cu. ft. Rectangular in shape, north, east, south shore lines - parklands; west shore - residential.

        4) Effectiveness: 75-95% removal of bacteriological loading (total coliform, fecal coliform, fecal streptococci) from surface runoff to south shore embayments during low to medium storm events (i.e., 1 inch/24 hrs. or less). This type of storm event comprises the majority of the annual precipitation events.

        Suspended solids removals by the impoundment are in the range of 43-75% for low/medium storm events and 40-56% for larger storm events (i.e., more than 1"/24 hrs.).

        5) Cost: Negligible - possible dredging costs as impoundment becomes filled with sediment.

6) Problems: The impoundment does not appear to effect significant removals during larger storm events (i.e., more than 1"/24 hrs.). What appears to happen is a short circuiting of storm flow through the pond, allowing entering runoff to pass rapidly through or over the resident pond water. An example of such an occurrence was a storm event on September 15-16, 1981. A total rainfall of 2.44" was recorded during a 24-hour period. A comparison of EMC's of influent and effluent bacteriological parameters indicate no removal of total or fecal coliform bacteria. There was a corresponding 75% removal of fecal streptococci.

b. In-line stormwater storage drainage system

1) Location: Northeast Nassau County, Inc. Village of Bayville

2) Drainage Area: 65.6 acres of which 100% is medium density residential with 15% impervious land surface (9.8 acres).

3) Description: Separate storm sewer system consisting of a series of interconnected leaching pools (10' diameter reinforced concrete perforated rings - 3 rings deep - 18') located below the street right of way into which stormwater flows from 6' diameter leaching type catch basins (12' deep). Interconnecting piping is perforated to facilitate recharge to groundwater. Stormwater runoff first enters the leaching catch basins. Once these basins are full and the influent of runoff exceeds the leaching rate, the basins overflow to the larger leaching pools located in series along the main storm sewer line. As each pool fills to maximum capacity and if the rate of influent exceeds the leaching rate of the pool, the effluent will overflow to the next pool downstream. The entire system produces a discharge to the estuarine receiving water (Mill Neck Creek) only when the storage and leaching capacity of the system are exceeded.

4) Effectiveness: Since construction of the system was completed in the fall of 1979, there has been evidence of system overflow to the receiving water on two or three occasions. These occurrences were during storm events with rainfall intensities of five inches/hour or more (e.g., intense thunderstorm activity). The majority of storm events for this locale are much less intense and permit retention and recharge of the runoff to groundwater.

5) Cost: Construction costs for the installation of the Perry Avenue In-Line Storage Sewer System was $836,855 (1979). Cost covered all phases of construction including installation of leaching basins, pools and drainage pipe, sidewalk and curb reconstruction and roadway regrading and resurfacing.

The system includes 31 recharge-leaching pools, each consisting of 10' diameter reinforced concrete rings with concrete slab cover, 28 leaching catch basins, each consisting of 6' diameter reinforced concrete rings with concrete slab covers, curb inlets and road grates and interconnecting reinforced, perforated concrete pipes ranging from 15" to 42" diameter.

6) Problems: There have been some problems with subsidence of soils surrounding the mainline leaching pools. This problem is seen more as a problem with installation of the leaching rings and proper backfilling than with the design of the system.

The effectiveness of the system may decrease with age as clogging of soil pores continues. Sediment and leaf removal from the leaching catch basins is necessary on at least an annual basis to maintain proper functioning of structures.

2. Suffolk County Department of Health Services

a. Orowoc Creek - Dry stream channel, energy dissipation/wetlands
   1) Location: South Brentwood, New York
   2) Drainage Area: 190 acres, all medium density residential
   3) Description: The site is at a trapezoidal shaped recharge basin just to the north of the Southern State Parkway in South Brentwood, Islip town, located on the service road to the parkway. The basin is approximately 450' long and 300' wide at its longest and widest points. There is a storm drain draining a small residential area that discharges into the east side of the basin, roughly 200' downstream from the stream influent point at the northern end of the basin. A low (8"-10" high) concrete wall at the end of the 10' long concrete apron to the storm drain, which has been in place for at least 15 years, acts as a working, effective energy dissipator. The basin and stream channel upstream are heavily overgrown with wetlands vegetation and, hence, provide an effective site for wetlands treatment. Upstream of the recharge basin, the channel is dry for much of the year and resembles the conditions predicted in the Suffolk County Flow Augmentation Needs Study (FANS) for streams without augmentation.
   4) Effectiveness: Unknown (as yet untested). SCDHS has been looking for a site that may be monitored to assess the stormwater runoff treatment benefits that may be derived from the drying up of portions of streams due to the effect of sewering. SCDHS proposes to (a) establish a monitoring station at the basin influent to evaluate the treatment provided by the dry stream channel, (b) have a monitoring station at the storm drain discharge to the basin, to sample runoff from the small residential area and (c) sample at the basin effluent to evaluate the treatment provided by the wetlands vegetation and from recharge in the basin.

   Because of the existence of heavy vegetation in the channel up-stream and also in the recharge basin, it is anticipated that there would be several storms for which there may not be any flow measured at the basin's influent or effluent points. If conditions of no flow do occur as expected, then a consequent total removal of pollutants to surface water will have been achieved as a result of energy, dissipation, retention, and percolation.
   5) Cost: Negligible - no routine maintenance costs.

6) Note: SCDHS is dropping the energy dissipation construction at Westview from the study for three (3) reasons:

(1) the low bid for constructing the facility was $41,000, which was approximately $20,000 more than the LMS estimate;

(2) although SCDHS' field crew had identified 40 to 50 potential sites where energy dissipation could be implemented, the total contributory drainage area to these sites is not as significant as originally envisioned before the site inspections were done; and,

(3) energy dissipation/wetlands treatment can be evaluated at the storm drain discharge to the Orowoc Creek site.

The Westview Avenue site would be retained in the monitoring program as a control for evaluating the impact of modifying the street cleaning practices at Central Avenue. It is intended to sample both sites during the same storm events.

b. Carlls River - Street sweeping

1) Location: Deer Park, New York

2) Drainage Area: 73 acres, all medium density residential

3) Description: An area of 73 acres draining to Central Avenue is being used to investigate the impacts of varying frequencies of street sweeping on stormwater runoff quality. Sampling will be conducted at a manhole at Central Avenue and W. 42nd Street which discharges to a 45" x 72" oval drain.

4) Effectiveness: Unknown (as yet untested). Monitoring will be conducted from March 1982 through the Fall of 1982. This work should be done because street sweeping appears to be one of the few control options for addressing the contamination attributable to direct runoff to the bay.

5) Cost: Approximately $600 per sweep (both sides of street). Frequency of sweeping is anticipated to be weekly, thus the total cost (capital plus O & M) for the program is approximately $15,000-$20,000.

3. U. S. Geological Survey

a. Stormwater recharge basins

(All basins are approximately 1-3 acres in size and 14-40 feet deep).

(1) Basins:

(a) Plainview, N. Y.
-land use - major highway
-drainage area - 190 acres
-% impervious - 6.3

(b) Syosset, N. Y.
-land use - medium density residential (1/4-acre zoning)
-drainage area - 28.2 acres
-% impervious - 16

(c) **Laurel Hollow, N. Y.**
-land use - low density residential (2-acre zoning)
-drainage area - 100 acres
-% impervious - 4.7

(d) **Huntington, N. Y.**
-land use - parking lot and shopping mall
-drainage area - 39.2 acres
-% impervious - 100

(e) Centereach, N. Y. (N.Y.S. Dept. of Transportation Ecological Recharge Basin: lined with plastic; holds water permanently up to predetermined level, above which exfiltration occurs through basin walls)
-land use - strip commercial
-drainage area - 68 acres
-% impervious - 6

(2) Effectiveness:

(a) Bacteria: virtually 100% removal of total coliform, fecal coliform, and fecal streptococci after infiltration to the water table.

(b) Heavy metals: high concentrations in stormwater (up to 3 ppm Pb, for example) reduced by 1-2 orders of magnitude.

(c) Nitrogen: low concentrations of total nitrogen in stormwater (median values of 1-3 mg/l) indicate that stormwater is not a significant contributor of nitrogen to groundwater.

(d) Chlorides: these ions tend to be conservative and are not removed during infiltration. Median concentrations are low (≤ 20 mg/l) except in the parking lot area, where the median concentration is 78 mg/l.

(e) Priority pollutants: an extremely limited number of analyses indicates that priority pollutants in stormwater and groundwater are below the recommended limit of 10 ug/l with two exceptions: 1,1,1 trichloroethane in Huntington groundwater is 23 ug/l, and 4,4-DDT in Plainview stormwater is 30 ug/l (based on one analysis only).

(3) Costs:

The only costs associated with recharge basins on Long Island are the initial costs of construction, implacement of security features such as fences, and landscaping. No maintenance is required due to the sandy, porous nature of the soil.

(4) Recharge basins located in shopping center areas tend to become clogged with oil debris, reducing their effectiveness and causing them to hold water at all times. However, all recharge basins on Long Island are large enough so that this does not present any serious problems.

III. PRELIMINARY CONCLUSIONS REACHED

A. SURFACE WATERS

1. The significance of urban runoff as a contributor of coliform loadings to surface waters, indicated in the L.I. 208 and ongoing monitoring studies, has been confirmed by extensive baseline sampling. When load contributions from point sources are factored out of the total loadings to the bays, it is found that coliform contamination levels remain high enough to keep shellfish beds closed.

2. Nassau and Suffolk Counties represent two entirely different situations in terms of runoff effects and control. The western south shore bays of Nassau are subject to much greater tidal flushing, which distributes loadings throughout the Nassau Bay System. The Suffolk portion of the bay is much more stable and, hence, tends to concentrate loadings close to their discharge points. To achieve load reductions in Nassau, controls must be instituted on a global scale, while in Suffolk reductions can be achieved using localized controls.

3. An extensive stormwater runoff modeling effort developed for the study has indicated that a reduction of total coliform loads of one to two orders of magnitude (90 - 99%) will lead to surface waters that meet current water quality standards in many areas.

4. Land uses within stream drainage basins have been disaggregated in an attempt to quantify the proportion of runoff from streams versus the proportion attributable to direct overland runoff to tidal waters. It appears that approximately 45% of the total coliform load from runoff in Nassau and 25% of the total in Suffolk can be attributed to overland runoff.

5. Coliform removals from runoff of 75 - 95% have been observed in Unqua Pond. This is probably attributable to natural processes (settling, filtration) acting on runoff. The removals observed appear to be inversely related to rainfall magnitude (volume and intensity). High removals have been observed for low volume, low intensity storms, which comprise the majority of Long Island precipitation events. Poorer removals have been observed for high volume, high intensity storms.

6. The in-line storage system with leaching pools performs very effectively, but appears to be hydraulically over-designed.

7. The use of stream corridors to replicate the natural processes observed in ponds (detention, settling, filtration) offers a promising means of achieving a significant degree of runoff control. However, to achieve the further reductions needed to meet bay water quality standards, overland runoff from shoreline areas draining directly to tidal waters must also be controlled.

8. Extensive sewering, with resultant lowering of water levels, and a reduction in the pace of development in Nassau County will tend to reduce runoff pollution without further planning and control, and may help to solve Nassau's runoff problems. However, active planning and control is needed in Suffolk, because increasing development in the eastern portion of the county will increase pollutant loadings to runoff and the bays.

9. Direct overland runoff, which appears to contribute approximately 40% of the bacterial loading to the bays in Nassau County and 25% in Suffolk County, is generally not amenable to the same type of control that is effective in a stream corridor.

10. The original 208 surveys and stormwater sampling implicates dogs as the primary contributors of coliform bacteria to surface waters. Preliminary examination of NURP fecal coliform-fecal streptococci ratios support this finding.

11. There is evidence that large waterfowl populations on ponds contribute a significant portion of the total coliform load to the ponds; small populations do not. Opportunities for control are limited.

12. With little remaining vacant land and, hence, few opportunities for additional development, changes in land use in Nassau County over the next twenty to thirty years will not have a significant impact on pollutant loadings in runoff. Similarly, there is expected to be little if any change in western Suffolk. Loadings from land in Brookhaven and points east, however, are expected to increase with projected increases in development.

B. GROUNDWATERS

1. The practice of collecting urban stormwater runoff in recharge basins and allowing it to infiltrate to the groundwater does not appear to constitute a threat to the quality of the groundwater resource on Long Island.

2. Bacteria carried by runoff do not seem to reach the water table via infiltration. Removal of total coliform, fecal coliform and fecal streptococci, during infiltration to the water table, is virtually 100%.

3. Heavy metals are reduced by infiltration by several orders of magnitude, down to detection limits.

4. There seems to be no adverse impact on groundwater from nitrogen in runoff, but it is difficult to tell since nitrogen from other sources is almost always found in groundwater.

5. Chlorides seem to be totally unaffected by filtration and seem to pass freely through the unsaturated zone. Low median concentrations were found at all sites except the Huntington parking lot.

6. A limited number of priority pollutant analyses indicates that priority pollutants in stormwater and groundwater are below the recommended limit of 10ug/l with 2 exceptions: 1,1,1-trichloroethane in Huntington, and 4.4-DDT in Plainview.

7. Most basins appear to be functioning satisfactorily, and in fact most seem to be over-designed. No special maintenance seems to be required.

IV. FURTHER INVESTIGATIONS

Useful further investigations would include the instrumentation and evaluation of recharge basins draining other land-use types, more extensive analysis of stormwater and groundwater for priority pollutants, and analysis of water and/or sediment in the unsaturated zone beneath the recharge basins to determine how and where the removal of certain stormwater constituents occurs. Additional computer modeling of rainfall-runoff relationships would be extremely useful in the prediction and evaluation of direct runoff constituent loadings to Great South Bay.

Investigations to permit the refinement of pond modification designs for increased detention of runoff and enhanced bacterial dieoff appear likely to yield significant benefits.

Continuation and possible expansion of the NURP salmonella study should be helpful in addressing the question of an appropriate standard for the certification of shellfishing areas. Inasmuch as Long Island runoff sampling suggests that a large part of the coliform loading is of non-human origin, it would seem useful to look for the presence of human pathogens rather than indicator organisms before closing shellfishing areas. The salmonella study is expected to complement an on-going Suffolk County study of the concentrations of bacteria and other pathogenic organisms in the water column and in the meat of shellfish.

NATIONWIDE URBAN RUNOFF PROGRAM

BALTIMORE REGIONAL
PLANNING COMMISSION

BALTIMORE, MD

REGION III, EPA

I. Project Location:

Baltimore City/County, Maryland

II. Project Description:

A. Urban Runoff-related Problems Observed

The Jones Falls Urban Runoff Project (JFURP) has observed a range of possible problems through both its receiving waters and small catchment sampling. If a water quality "problem" is described by EPA's three level definition, the observations may be interpreted as follows:

Violation of State Standards - During storm runoff, receiving waters stations have exhibited violations in turbidity and fecal coliform bacterial indicators. Dry weather, base-flow conditions have also shown periodic bacterial violations. Priority pollutant sampling has not been implemented for comparison with new state pesticide standards. Small homogeneous catchments as well as receiving water stations downstream of more urbanized areas have exhibited some heavy metals event mean concentration levels that exceed EPA criteria; lead concentrations, for example. No state standards presently exist for nutrients, although event mean concentration values for total phosphorus seem to be significant.

Denial or Impairment of Beneficial Use - Data collected to date (11/81) has not identified a direct denial or impairment of beneficial uses. For example, children are periodically seen playing and wading in the Stony Run stream, where fecal coliform levels have been documented at levels greater than 10^5 MPN/100 mL, with no apparent ill effects.

Public Perception of a Problem - Communications with various publics in the watershed have not yet revealed a true perception of a problem in the Jones Falls. However, two problems related to urban runoff have been identified by the public: localized flooding and rapidly eroding streambanks. In the past, private citizens have been sufficiently concerned about the aesthetics of the Jones Falls and its tributaries to sponsor massive one-day clean-up campaigns.

B. Where

Bacterial violations have been observed at all three receiving stream stations - both up and downstream of the urban area. The five small homogeneous catchments, ranging in land use from low to high density residential and mixed residential-commercial, have all exhibited violations.

Severe streambank erosion has occurred along both the Western Run and Stony Run tributaries and the Jones Falls mainstream. Most noticeable, however, is the Western Run which was subjected to intensive rainfall and resultant flooding in 1977 from Hurricane David.

C. How Often

Analysis of data is not complete at this time.

D. How Severe

Analysis of data is not complete at this time.

E. Under What Circumstances

Analysis of data is not complete at this time.

F. Local Legal and Political Implications and Public Attitudes

Through the past 208 Water Quality Management Planning process, member jurisdictions and the private sector have become more aware of problems in the region's waters and that nonpoint sources (including urban runoff) may be a major contributing factor. As the emphasis has shifted from planning to implementation, certain programs are being changed or initiated to better reflect water quality objectives. However, the earlier 208 studies only identified the presence of nonpoint sources and a possible relationship to resulting problems. A definitive quantification and description of urban runoff quality and its effects in receiving waters has not been determined. In the highly developed urban areas where urban housekeeping management practices seem to be more feasible then structural controls, local governments believe their present levels and types of practices are adequate. Also, with present economic limitations, an increase in practice applications may not be justified when compared to other governmental needs. Perhaps the "best" management strategy achievable will be one in which the application of current management practices will be optimized with some attendant positive results in water quality. JFURP results, both in pollutant contributions, effects and "best" methods of control, should better define the balance needed in water quality objectives achievement and increased or modified costs.

G. BMP's Investigated

During the JFURP Study, a range of BMPs are being investigated. These include an old water supply impoundment (60 acres), now a recreational lake, and a range of non-structural urban housekeeping practices. Inputs, outputs, and lake quality are being monitored to determine its effectiveness as a detention structure. Housekeeping practices under study include manual and mechanical street/alley cleaning, storm inlet maintenance, domestic animal litter control, and general sanitation practices.

1. Effectiveness of BMPs - not available at this time
2. Costs of BMPs - not available at this time

E. Problems - none so far

III. Preliminary Conclusions Reached, Trends Indicated

The level of data analysis completed at this time does not allow preliminary conclusions or trends to be reached.

IV. Further Investigations Indicated - none at this time. Additional data collection and analysis may reveal the need for further investigations.

188

NATIONWIDE URBAN RUNOFF PROGRAM

NORTH CAROLINA DEPARTMENT OF
NATURAL RESOURCES

WINSTON-SALEM, NC

REGION IV, EPA

I. Project Location

The Winston-Salem NURP project is located in Winston-Salem, North Carolina, in the county of Forsyth.

II. Urban runoff related problems observed

There are two major tributaries draining the county, Muddy Creek and Abbott's Creek; both streams drain into the Yadkin River, a major source of drinking water for many communities downstream. Both Winston-Salem study watersheds are in headwater areas of Muddy Creek. A major portion of the urban area drains into Salem Creek, a tributary of Muddy Creek, upstream of High Rock Lake.

The Muddy Creek watershed was monitored to determine its importance to water quality in High Rock Lake, a lake downstream of the confluence of Muddy Creek and the Yadkin River (High Rock Lake Study, Weiss). Between October 1977, and September, 1978, seventeen (17) river sampling points, which defined fifteen (15) discrete subbasins and twelve (12) lake locations were systematically sampled at a three week interval. Thirty (30) different water quality parameters were analyzed and defined in each sample.

Utilizing the total area for each subbasin as derived from a land use analysis (GIRAS maps), the average daily yield of the principal water quality parameters was calculated for each of the Yadkin subbasins. The relative magnitude of these yields can be assessed by comparing the Upper Yadkin (Station 1) draining approximately 4900 Km^2 with that of Muddy Creek (Station 2) draining 684 Km^2. In the seasonal period of April-November the Kjel-Nitrogen yield of the Upper Yadkin was 2596 grams/day/Km^2 whereas 684 Km^2 of the Muddy Creek subbasin produced 10,610 grams/day/km^2. Maximum seasonal yields for phosphorus were generated from the Muddy Creek subbasin. Of the heavy metals zinc has the highest yield at stations 2 and 1 (320 and 209 g/d/Km^2, respectively). Mercury was highest (3.6 g/d/Km^2) at Abbotts Creek followed by Muddy Creek (2.1 g/d/Km^2). Chromium in Muddy Creek (484 g/d/Km^2) and the main river (238 g/d/Km^2), were highest as was arsenic (289 g/d/Km^2) in Muddy Creek and the main river (176 g/d/Km^2).

The effect of changes in river flow on yield was further examined by comparing the ratio between maximum and minimum mean yields at the same station for each of river flow categories. From further analysis it was clear that Muddy Creek was exporting water degrading parameters at a rate several times or even orders of magnitude greater than the next largest exporter.

III. How often and how severe

Information on how often and how severe urban runoff problems are has not been developed at this time.

IV. Under what circumstances

Although within the NURP project this has not yet been determined, some inferences can be made from the 208 Urban Water Quality Management Plan. The N.C. 208 Program collected and analyzed limited data in Winston-Salem. For instance, mercury concentrations considered "problematic" (problematic is defined here as a concentration above the state water quality standards) occured more during low flow conditions than high flow (45% of samples taken during low flow versus 13% of samples taken during high flow). Lead and iron "problem" concentrations occurred in 100% and 92% respectively of the samples taken during high flow and 13% and 15% respectively of the samples taken during low flow. Pollutant concentrations were generally higher in the CBD than in the residential watersheds monitored.

V. Local, legal and political implications and public attitudes

Public attitudes toward urban runoff and/or the NURP project have been mixed. The project has received quite a bit of support from a segment of the area public; however, it has been a controversial issue also. It seems, even though there have been numerous efforts at public involvement, the general public remains unaware of stormwater runoff's environmental impacts.

VI. BMP's investigated

Street sweeping and catch basin cleaning are the BMP's being tested in the Winston-Salem study. Much of the data is still to be collected or stored on computer, therefore, the following BMP discussion is preliminary.

Effectiveness of BMPs

Street sweeping activities have been monitored in both residential and CBD land uses for sweeper efficiency as well as water quality. Also, street solids accumulation studies and sweeping program effectiveness have been investigated. One preliminary observation is that the sweeper can actually add solids to an area being swept if the initial street solids loading is small enough. This may be by breaking up larger particles into smaller ones, or by brush wear or by dropping solids picked up elsewhere. The trend that seems to be developing is the larger the initial load the better the removal of total street solids. Removals have been seen up to 40%. As expected, sweeping seems to be less efficient at the smaller particle sizes.

Cost of BMP's

Cost documentation is being prepared for both BMP's tested. During the cost document formulation we found various factors that influence cost and should be acknowledged in street sweeping program review. Among these are: (1) distance to dump area, (2) age and type of equipment, (3) age and type of road surface, (4) seasonal influences (leaf, snow, etc.), (5) distance to site. These and other factors (unless adequately identified) can make cost and program comparisons extremely difficult. Average total costs for residential street sweeping were determined to be $10.30/curb mile, and for CBD total cost was $6.41/curb mile (MRI Document, K. Rife). Average operating speed for the CBD is 4.7 curb miles/hour. For the residential average speed is 3.00 curb miles/hour. Cost effectiveness analyses will be included in the final report.

Problems

A complete problem description concerning street sweeping will be included in the final report. Presently the only problems noticed are: (1) initial data indicates that sweepers are not that effective on the small particle sizes, (2) regenerative air vacuum sweepers use water sprayers to control dust; however, vacuum sweepers freeze up when air temperature falls below 40°F. Catch basin cleaning has not proven to be an effective BMP for several reasons. First, most cities in N.C. have no catch basins they have drop inlets or junction boxes. This eliminates the detention treatment techniques. Since the outlet pipe is at the bottom of the tank, no settling occurs. These devices serve the purpose the city needs by eliminating clogging of drainage pipe. Quite a bit of manpower and resources go into cleaning of catch basins in Winston-Salem. They are cleaned on two schedules once per year and/or emergency stoppage. Therefore, problem catch basins are cleaned more frequently than the average ones.

Problems occur when the catch basins are cleaned and the cleaning equipment takes a lot of water into a holding tank which has to be emptied periodically. Emptying it in a sanitary sewer instead of a storm drain or creek bed would be more suitable.

Analysis of actual catch basin data has not begun.

NATIONWIDE URBAN RUNOFF PROGRAM

TRI-COUNTY REGIONAL PLANNING COMMISSION

LANSING, MI

REGION V, EPA

I. Project Location

Michigan, Ingham County, Lansing

II. Project Description

Recent monitoring efforts along the Grand River have documented the existing water quality, and identified nonpoint source pollution as a major contributor to biochemical oxygen demand, nitrogen and suspended solids. Fish ladders have been installed downstream at barriers which now permit salmon migration upstream into the Lansing area. With this potential recreational opportunity being realized presently, the public attitude, and that of the local governing bodies is strongly in favor of reducing pollution from urban nonpoint sources.

The Bogus Swamp Drain Drainage District was selected as a location where three alternative types of best management practices could be implemented, and their effectiveness evaluated. They include an in-line wet retention basin, two in-line up-sized (increased volume) lengths of storm drain, and an in-line dry detention basin.

Estimated cost of the wet retention basin with a runoff storage capacity above normal level of 83,000 cubic feet, is approximately $173,000.

The incremental costs for the increased diameter sections of storm drains (above that of the normally sized drains) totalled approximately $36,000. Pipes were 96 inch diameter, instead of 54 inch (needed for flow), and were 144 ft. and 85 ft. in length.

The remaining BMP is an existing depression comprised of several back yards, which floods on occasions when the existing drains prove inadequate to handle the total flow, which subsequently discharges the excess back into the storm drains, as the flows decrease. No costs have been developed for this existing condition.

Problems were encountered in scheduling the project in conjunction with the construction efforts required. Also, when sampling and monitoring were initiated, sanitary flows from illicit connections had to be corrected, along with improperly discharged industrial wastes.

III. Preliminary Conclusions Reached; Trends Indicated

Evaluation of the in-line wet retention basin has proved that it is very effective in retaining suspended sediment, total phosphorus, total Kjeldahl nitrogen, biochemical oxygen demand and lead. Efficiency of retention increases with an increase in storm size, based on data for the sizes of storm evaluated.

Results of evaluation of the in-line upsized storm drain sections have shown highly variable performance. One tentative conclusion is that the shorter section is probably too short for suitable settling times, given the small particle sizes encountered. The longer section has proved to be more effective in reducing sediment loads, and pollutants associated with them, although less effective than the wet retention basin.

The results obtained from the normally dry detention basin are still being evaluated, as event sampling was initiated later for this BMP. A very preliminary look at early results indicates that while it operates effectively for flood control, its effectiveness in reducing pollutants is poor.

IV. Further Investigations Indicated, In Pursuit of Answers to Original Questions and Concerns

Given the difficulty of locating space in urban settings for in-line wet retention basins like that investigated, the use of up-sized in-line storm drains to serve a similar purpose needs further evaluation. A longer length than either of those evaluated, and locations providing opportunities to evaluate different loading conditions, and over a range of storm events for all seasons, is suggested by evaluation to date.

NATIONWIDE URBAN RUNOFF PROGRAM

ANN ARBOR, MICHIGAN

REGION V, EPA

I. Project Location

Michigan, Washtenaw County, Ann Arbor

II. Brief Project Description

A. Urban Runoff Related Problems Observed

Earlier water quality surveys disclosed relatively good water quality conditions during dry weather flow, with dramatic increases in pollutant levels being experienced during stormwater runoff periods. Water quality standards violations have resulted.

B. Where, etc.

Studies identified the reach of the Huron River between the Argo and Geddes Dams as one of three problem areas. Nonpoint sources would be the primary source, since point source discharges do not exist in this reach.

Both the community and the State consider the river to be a recreational resource. Many past studies have been conducted by the University of Michigan, located in Ann Arbor. As a result, there has been considerable public awareness concerning the quality of water in the Huron River.

C. BMP's Investigated

Three BMP's have been investigated in this project. One was the Swift Run wetlands. This BMP has proved to be very effective for the range of storm event sizes sampled, for removal of solids and heavy metals. The effectiveness of nutrients removal appears to vary, depending on seasonal conditions.

The second BMP evaluated was the existing Pittsfield-Ann Arbor retention basin, designed to function as a flood control structure. It has proven to be quite effective in removal of solids, and pollutants associated with them. Appropriate modifications of the basin outlet structure, oriented towards water pollution control, would be expected to improve the functioning of this BMP in control of runoff pollutants.

The third BMP was an on-line detention basin constructed adjacent to Traver Creek. Although it will function as an off-line basin, while it was being monitored, it was operating as an on-line BMP. It demonstrated only minimal removal of pollutants, as tested. Construction delayed monitoring this project, and not as many events were sampled, as a result.

Costs are being developed for these BMP's, to be extent possible, but are not yet available.

III. Preliminary Conclusions Reached and Trends Indicated

The flood control wet retention basin in the Pittsfield-Ann Arbor Drain has demonstrated, for the range of events sampled and the seasonal coverage included, that water quality benefits are produced, also. The Swift Run Wetlands are also effective in the removal of pollutants, subject (in the case of nutrients) to seasonal variations. The Traver Creek Drain BMP has proven less effective, in part, it seems, due to the upstream sources of contributions (from a largely agricultural, less intensively developed area).

IV. Further Investigations Indicated in Pursuit of Answers to Original Concerns

Areas where further investigations would appear to be fruitful include the following:

1. For Traver Creek Drain, the BMP needs to be evaluated as an off-line structure, with further testing as urban-development occurs.
2. For Pittsfield-Ann Arbor Drain, the BMP should be evaluated after specific outlet structure modifications designed to improve pollution control, are implemented.
3. The results obtained during the evaluations described above should cover a wider range of storm events, and be conducted during all seasons to better understand the effectiveness variability that may result from different levels of runoff, during the different seasons.

NATIONWIDE URBAN RUNOFF PROGRAM

SOUTHEAST MICHIGAN COUNCIL OF GOVERNMENTS
OAKLAND COUNTY, MICHIGAN

DETROIT, MI

REGION V, EPA

I. Project Location

Michigan, Oakland County, Troy

II. Brief Project Description

The project was located in a relatively flat, poorly drained and highly urbanized area in southeast Michigan. Experience had demonstrated evidence of poor storm-induced water quality. In addition, a network of rain gages was in place in close proximity. Southeast Michigan Council of Governments studies have identified urban stormwater as an important factor in water quality degradation. This has become increasingly obvious as treatment of municipal and industrial sources has been implemented in the area. Given the poor drainage conditions, developers have been required to provide normally dry detention basins adequate for flood control purposes. Their design is such that they do not reduce pollutants included in urban storm runoff.

Three of these on-line basins have been selected for modification to provide pollutant removal. The project to date, has evaluated the pollutants and concentrations prior to actual modifications to determine a base against which to compare results following the basin modifications. Sampling for this purpose will be accomplished in the spring of 1982, now that modifications have been accomplished. A problem of keeping all the monitoring and sampling equipment operating during any given event has limited the usable data obtained during the initial phase.

Legal and institutional aspects of an implementation program are under review as well, and recommendations concerning needs in these areas will be another end product of this project.

III. Preliminary conclusions reached

Until the event monitoring and sampling of the modified basins has been completed, and evaluation of results obtained can be done, no conclusions can be drawn.

IV. Further Investigations Indicated in Pursuit of the Answer to the Original Question

Other than a need to establish a much larger data base, followed by a much increased sampling and monitoring program of modified structures, to include a wide range of storm events for all seasons, it is too soon to determine other potential investigative needs.

NATIONWIDE URBAN RUNOFF PROGRAM

NORTHEASTERN ILLINOIS PLANNING COMMISSION

CHICAGO, IL

REGION V, EPA

I. Project Location:

Glen Ellyn, DuPage County, Illinois

II. Project Description:

A. Urban runoff-related problem observed

Algal blooms and low dissolved oxygen (DO) levels.

B. Where

Detention Basin

C. How Often

Algae - Spring, Summer and Fall.

Low dissolved oxygen - Summer, occasionally.

D. How Severe

Algae - blooms quite visible.

DO - < 5 near the lake bottom.

E. Under What Circumstances

Algae - almost any time.

DO - quiet days, warm temperatures.

F. Local, Legal and Political Implications and Public Attitudes.

No legal or political implications at present. Public unconcerned, since principal recreational uses (ice skating, aesthetics and fishing) are not yet seriously impaired.

G. BMP's Investigated

Wet bottom detention - effectiveness not yet calculated but thought to be about 90% for suspended constituents. No costs have been assembled yet. No problems related to the evaluation have been experienced.

III. Preliminary conclusions reached, trends indicated

Wet bottom detention is very effective in removing suspended constituents for this particular case. There have been no conclusions drawn yet concerning pollutant sources. It appears that about 75% of the load to the detention basin is less than 63 microns in size. Little or no material is being retained in most catchbasins.

IV. Further investigations indicated in pursuit of answer to original questions/concerns.

Further investigation is needed on the availability of constituent pollutants for uptake by benthic organisms. There is concern that pollutant constituents in detention basin sediments may become mobile and available to the water column under changing conditions of pH, DO or chloride, as well as uptake by lake bottom benthic organisms, and the potential for bio-accumulation in fish. An additional concern relates to the question of habitat, and whether the limiting constraint on aquatic organisms is pollutant related or habitat related.

NATIONWIDE URBAN RUNOFF PROGRAM

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY AND
ILLINOIS STATE WATER SURVEY DIVISION

CHAMPAIGN, IL

REGION V, EPA

Project Location

Illinois, Champaign County, City of Champaign.

Project Description

History of Urban Runoff Related Problems

Champaign was one of eight SMA's studied in the 1978 208 urban stormwater assessment. The urban assessment for Champaign indicated that general water use standards are exceeded between 20-30 times a year for lead, copper and iron. The once a year maximum for these concentrations could be 15-20 times higher than the standard. Mercury was regularly observed in stormwater samples and could be expected to exceed the standard 10 times a year. Total suspended solids and total dissolved solids were also frequently high.

Public Attitudes

During the 208 urban stormwater assessment an Urban Stormwater Task Force composed of 8 local steering committees assessed the IEPA's study. The Champaign local steering committee concurred that there was an urban runoff pollution problem but felt additional data was necessary to determine whether urban stormwater runoff was a detriment to fishable and swimable water quality, whether current general use standards were applicable to urban stormwater pollution, and the relative impact of urban runoff in relation to other pollution sources.

The local steering committee strongly supported intensive monitoring of a local basin to clarify the above issues. In addition, the committee supported less expensive BMP's such as optimized street sweeping, monitored road salting and on-site runoff control ordinances.

Project Description

The Illinois NURP is evaluating the use of municipal street sweeping as a BMP for the improvement of urban stormwater quality. Eight major project objectives are:

1. To relate the accumulation of street dirt to land use, traffic count, time, and type and conditions of street surface.
2. To define the washoff of street dirt in terms of rainfall rate, flow rate, available material, particle size, slope and surface roughness.
3. To determine what fraction of pollutants occurring in stormwater runoff may be attributed to atmospheric fallout.
4. Modify the ILLUDAS model (1) to permit examination of the functions determined in objectives 1 through 3.
5. To calibrate the modified model on all instrumented basins.
6. To identify sources of pollutants in the urban environment.
7. To determine, if possible, the influence of deposition and scour in the pipe system on runoff quality.
8. To develop accurate production functions and corresponding cost functions for various levels of municipal street sweeping. (Bender et al. 1981)

Four basins have been monitored since 1979: 2 paired single family residential land use basins and 2 paired commercial land use basins. In addition, a microbasin with a single curb inlet and no pipe flow is being examined for the washout characteristics of surface flow.

All four basins are being measured for rainfall and runoff quantity and quality, contribution by atmospheric deposition, street dirt load, accumulation rates and particle distribution. Concentration analysis is being completed for lead, iron, copper, total suspended solids, chemical oxygen demand, phosphorous, K-Nitrogen, nitrite, ammonia, chloride and sulfate. Eighty-three events have been monitored and 1663 samples collected between November 1979 and July 1981.

BMP Investigated

Street sweeping in one of each paired basin occurred while the other remained unswept. In the summer of 1980 each experimental basin was swept twice weekly. As the study progressed, the frequency was switched to once a week and the basin treatments were reversed so the original control basins were swept and sweeping in the original experimental basins terminated. A three wheel mechanical sweeper was used for sweeping. Preliminary results for sweeper efficiency are presented below.

Removal Efficiency by Particle Size

	PERCENT REMOVED	
Portion of Load	Mattis South (Commercial)	John North (Residential)
TOTAL	23	36
>3350 microns	24	61
3350-2000 microns	24	36
2000-1000 microns	25	39
1000-500 microns	26	36
500-250 microns	25	25
250-125 microns	18	15
125-63 microns	6	10
<63 microns	6	-5

(Table from Bender et al. 1981)

Based on 1980 figures, it has been estimated that sweeping costs $13.89 per curb mile. Proper percentages for parts replacement, major repairs, fringe benefits and overhead were not calculated into the cost per curb mile which has resulted in a curb mile cost which may be lower than actual cost. This information is currently being analyzed and a new estimate of cost per curb mile is being calculated. In a survey of 15 Illinois Municipalities, Public Work Departments estimated sweeping costs of between $4.98 - 220.60 per curb mile.

Preliminary Conclusions and Trends

An analysis of the 1980 basin load data indicates that sweeping twice a week has a large impact on measured street load. Load was reduced approximately 63% in the residential basin and 24% in the commercial basin.

Limited analysis has been made on water quality data so no conclusions about sweeper effect on pollution concentration can be made. However, there is an indication that sweeping in the residential basin may have a negative effect on water quality because more material is washed off the swept basin versus an unswept basin. Additional analysis on the other basins must be made before conclusions can be made.

Future Investigations

Further analysis will be made to determine the effect of sweeping on water qulaity by: additional comparisons of runoff quality from swept and unswept basins, from experimental basins before and after the sweeping program was initiated and simulation with the Q-Illudas water quality model.

The next phase of NURP will examine the effects of urban runoff on receiving streams. Water quality upstream and downstream of the City of Champaign will be monitored.

Reference

Bender, Michael G., Michael L. Terstriep, and Douglas C. Noel. 1981. Second Annual Report. Nationwide Urban Runoff Project, Champaign, Illinois. Evaluation of the Effectiveness of Municipal Street Sweeping in the Control of Urban Storm Runoff Pollution. Illinois State Water Survey, Urbana, Illinois. 82 pp.

WBC:jk/sp/2377c,1-6

NATIONWIDE URBAN RUNOFF PROGRAM

WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

MADISON, WI

REGION V, EPA

SUMMARY OF MILWAUKEE COUNTY NURP PROJECT

I. Project Location

Milwaukee, Milwaukee County, Wisconsin

II. Summary of Findings:

The purpose of this project is to characterize urban runoff, to identify urban runoff contaminant problems, and to evaluate street sweeping as an urban runoff control practice.

A. Urban Runoff Water Quality:

Several urban runoff contaminants have been observed at concentrations above that considered to be serious. These include metals (lead, zinc, cadmium and copper), suspended solids, and fecal coliform. Nutrients and BOD were not found at excessive concentrations and were generally much lower than Wisconsin's guidelines for sewage treatment plants.

The determination of 'problem' metal concentrations is based on the proposed 'White Book' criteria published in the Federal Register (V45, N231, November, 1980). 'Problem' concentrations were deemed to be the acute toxicity concentrations for freshwater aquatic life, "not to be exceeded at any time." These maxima concentrations are locally dependent upon the hardness of the receiving waters (for the Milwaukee area, 250 mg/l is a representative value for average event flow hardness concentration). The analyses to date have been able to identify the location, frequency and extent of urban runoff problems. Circumstances under which these problems occur, however, have not been identified, i.e., the effects of antecedent conditions and rainfall characteristics on concentrations remains unknown.

Lead:

Acute toxicity concentration: 526 ug/l. Thirty-six (36) and eighteen (18) percent of the event mean concentrations at the commercial and high density residential areas respectively exceeded this concentration. Small percentages (one (1) and four (4)) of the events at the medium density residential areas and the parking lots also exceeded this concentration.

Zinc:

Acute toxicity concentration: 687 ug/l. Sixteen (16) percent of the events at the commercial areas exceeded this concentration, as did one (1) and two (2) percent of the medium density residential areas and the parking lots respectively. There is presently insufficient data at the high density residential areas to make an evaluation of this contaminant.

Cadmium:

Acute toxicity concentration: 8 ug/l. This concentration is frequently exceeded at the commercial areas and at Rustler (a parking lot), but not at the other areas.

Copper:

- Acute toxicity concentration: 52 ug/l. This concentration is frequently exceeded at Wood Center (a commercial area) but not at the other areas.

Suspended Solids:

Wisconsin does not have an ambient stream standard for suspended solids. The State's guidelines for sewage treatment plant effluent however specify a maximum 30 day average of 30 mg/l, and a maximum 7 day average of 45 mg/l. Seventy-five percent of all suspended solids event mean concentrations exceeded 30 mg/l, 50 percent exceeded 67 mg/l, 25 percent exceeded 150 mg/l, and 10 percent exceeded 300 mg/l. Concentrations at the commercial areas and at Lincoln Creek (a high density residential area) greatly exceeded concentrations at the other areas.

Fecal Coliform:

Wisconsin has a fecal coliform ambient stream standard such that not more than 10 percent of the samples taken over a 30 day period can have fecal coliform counts that exceed 400 mpn/100 ml. Ninety percent of all of the urban runoff samples collected exceeded this level, and twenty (20) percent exceeded 50,000 mpn/100 ml.

Based on a recent survey of 1,000 people in the Milwaukee area, 95 percent of the respondents believe that there are significant water quality problems, but only 23 percent believe that urban runoff is a significant pollutant source. Less than 10 percent of the respondents objected to increased expenditures for nonpoint source pollution control.

B. Street sweeping as an urban runoff control practice:

The experimental design of the project incorporated traditional test and control design concepts, i.e., test areas, where the sweeping frequencies varied between baseline and accelerated levels, and control areas where the frequencies were held constant at baseline levels. There is considerable unexplained variability in urban runoff concentrations however. Even under the control situation there exists extreme fluctuations in the data base, i.e., when paired test and control areas were swept at the same frequency, there were very inconsistent relationships between their respective event mean concentrations. Given this poor signal to noise ratio, it is very difficult to extract meaningful information. There was found to be no demonstrable, statistically significant impact of accelerated street sweeping on any water quality parameter. Whether there was in fact no impact, or the impact was minor relative to the noise, is indeterminable.

III. Preliminary Conclusion Reached:

The degraded condition of urban runoff poses serious threats to freshwater aquatic life and to human body contact recreation. These threats arise from high levels of suspended solids and fecal coliform draining from most urban areas, and of toxic metals from heavily developed commercial and (to a lessor degree) high density residential areas. Frequent street sweeping was not found to be effective in reducing these contaminants.

IV. Further Investigations Indicated:

A major weakness in interpreting the impacts of high concentrations of contaminants lies in the inadequate understanding of on-site and synergistic impacts of high event-flow concentrations on aquatic organisms. Although event concentrations can be compared to established or promulgated criteria, (generally set for low-flow conditions), extrapolating from those criteria to actual in-stream impacts is a far more nebulous and uncertain affair. Further research is needed to ascertain the actual in-stream impacts of high event-flow concentrations.

0948A

NATIONWIDE URBAN RUNOFF PROGRAM

METROPLAN

LITTLE ROCK, AR

REGION VI, EPA

I. Project Location:

Little Rock, Pulaski County, Arkansas

II. Project Description:

A. Urban runoff-related problems observed

Pollutants identified as contributing to water quality problems are excessive coliform concentration, low pH and dissolved oxygen levels, high phosphorous and heavy metals concentrations, and violation of the water quality standards for BOD and suspended solids.

B. Where, etc.

Water quality problems related to urban runoff were observed in the Fourche drainage system, which includes a proposed public use area in Fourche Bottoms, where present poor water quality (high bacterial counts) precludes water based recreation. The city, the county, the health department and the University of Arkansas at Little Rock are actively cooperating to control flooding and upgrade water quality in the Fourche system.

Water quality problems were identified during the first year sampling program, conducted to discover background conditions. The second phase of the investigation will include sampling to evaluate the effectiveness of BMP's that are now in place or being installed. The BMP's being checked are sodding and rip rap along stream banks, gabions, channel clearing, vegetation, and low water check dams.

III. Preliminary conclusions reached, trends indicated

BMP evaluation has not resulted in any conclusions being reached or trends indicated, at this early time in the project.

IV. Further investigations indicated, etc.

The project has not yet progressed to the stage where further investigations can be identified.

NATIONWIDE URBAN RUNOFF PROGRAM

TEXAS DEPARTMENT OF WATER RESOURCES AND
CITY OF AUSTIN, TEXAS

REGION VI, EPA

I. Project Location:

Austin, Travis County, Texas

II. Project Description:

A. Urban runoff-related problems observed

The results obtained so far indicate that high fecal coliform counts were the most distinct characteristic of the runoff loadings from both stormwater runoff and receiving water stations. Other runoff-related receiving water impacts were elevated levels of alkalinity, TSS, ammonia, total phosphorus, BOD, and bacteria in the lake waters. Ammonia concentrations were found to exceed .5 mg/L during several runoff events. There was an increase in water treatment cost for the production of drinking water which correlated with runoff events when the cumulative rainfall volume was greater than one inch. Town Lake (the most urbanized receiving water) generally has bacteria levels 5 to 6 times greater than that of Lake Austin. During storm events, this variation is greater. Also, some heavy metals (lead, zinc) and pesticides (DDT and metabolites) have been found in significant levels in the sediments.

B. Where - N/A

C. How Often - N/A

D. How Severe - N/A

E. Under What Circumstances - N/A

F. Local Legal and Political Implications and Public Attitudes

The local populace is very concerned with environmental issues. These attitudes are concerned with aesthetic and environmental issues relating to development in the Austin area. Accordingly, the results of this NURP project will receive close scrutiny from the Council, economic interests, and the populace as a whole.

G. BMP's Investigated

As part of the local NURP study we have investigated a stormwater detention basin as well as non-structural controls in the form of three levels of impervious cover.

1. Effectiveness of BMP's

a. Stormwater Detention Basin - The basin under investigation seems to be somewhat effective in removing TSS (67%), and marginally effective in removing ammonia (27%) and TKN (26%). It is felt at this time that insufficient data exists to draw broad conclusions.

b. Non-structural controls. At the present time data indicate that the storm average concentrations of most pollutants seem to be about the same for each of the two test watersheds given similar physical conditions. However, data has shown that the total runoff volume (on a per acre basis) is significantly lower for the Rollingwood (low impervious cover -- 21%) watershed than for the Northwest Austin (high impervious cover -- 39%) watershed, hence the Rollingwood watershed contributes significantly less pollutant mass (lbs/acre) than does the Northwest Austin watershed under similar physical conditions.

2. Cost of BMP's - not available at this time

3. Problems - The study ran for only 7 months of data gathering (March-September), due to unexpected flood damage and equipment malfunctions, where it was originally designed to collect one year's data. As a result, seasonal variations cannot be accurately shown. Also, inflow/outflow data at Woodhollow Dam is rather sparse.

III. Preliminary Conclusions Reached, Trends Indicated

Characteristic runoff-related receiving water impacts were elevated levels of alkalinity, TSS, ammonia, total phosphorous, BOD and bacteria in the lake waters. During the course of the receiving water study, it has been observed that the short-term impact of the "conventional" pollutants on the Town Lake-Lake Austin receiving waters has been limited both spatially and temporally. The impact of the discharge plume from the tributaries to the lakes has been limited to those areas immediately downstream of the tributary confluence with the receiving water and in near-shore areas of the lake nearest the tributary. These effects also are limited from only a few hours to several days after the storm event, depending on the parameter being examined and the strength of the storm (intensity and duration). Unfortunately, comparison with upstream dam releases is not complete. Native biota do not seem to be negatively impacted by these discharge plumes. Long term effects of runoff on the receiving waters are still under investigation, and trends and conclusions cannot be meaningfully determined at this time.

Conclusions may be reached regarding the stormwater monitoring program from the data now available to the project. It has been seen that the storm-averaged concentration of most pollutants may be correlated rather well with dry days between runoff events, as well as total volume of runoff and storm intensity, in addition to other parameters. In many cases this correlation is quite good. Equations are presently being developed to describe the storm-averaged concentrations in terms of some of these parameters. In addition, runoff co-efficients also correlate very well with dry days between storm events. Peak fluxes (lbs/hour) of COD, TOC, NH_3-N, and Total P correlate well with peak flows at the monitoring sites and the flux curves for most pollutants tend to closely follow the general shape of their associated hydrographs. There is a definite trend toward higher runoff coefficients with an increase in impervious cover. Medium density residential land use (39% impervious) does produce a larger runoff pollutant load than a low-density residential land use (21% impervious). Neither developed watershed demonstrated significantly higher concentrations of detected parameters upon comparison, but were significantly higher than the undeveloped control watershed at Turkey Creek.

IV. Further Investigations Indicated -

A. Continuation of sampling at the Woodhollow Dam site to get sufficient data for a statistically significant determination of its efficiency in removal of pollutants.

B. A seasonal study of the lake that takes in fall and winter conditions.

C. A study of the bacterial levels from the tributaries and the sources and types of contamination.

NATIONWIDE URBAN RUN-OFF PROGRAM
DENVER REGIONAL COUNCIL OF GOVERNMENTS
DENVER, CO
REGION VIII, EPA

DENVER REGIONAL URBAN RUNOFF PROGRAM

Adams, Arapahoe, Boulder, Denver, Douglas and Jefferson Counties

The Denver region, situated at the foot of the Rocky Mountains, receives only about 14 to 15 inches of precipitation each year. About one-third of this total occurs as snowfall in the winter months. The snows usually melt rapidly within three to four days. However, there may be one or two periods where the snow remains on the ground for more than a week at a time. Lead and other airborne particulate matter will accumulate in this pack but generally the snowfall will be of significant water equivalent to provide enough water during snowmelt runoff to dilute the concentrations of most chemical constituents so as not to pose a problem in the receiving waters. Salt loadings are higher during these periods, as one might expect from street sanding and salting operations, but measured chloride concentrations are considered not to approach problem levels for aquatic life in the streams.

During the remainder of the year approximately eight or nine inches of rain will fall. Two rainfall regimes are apparent: 1) frontal systems in early spring and fall which produce long, gradual, light rains; and 2) convectional systems, summer thunderstorms characterized by localized heavy rainfall of short duration. It is these high intensity rains in the late summer during low flow conditions that produce the greatest loads of contaminants. Atmospheric deposition during long intervals between rains, oftentimes for weeks at a time, has a chance to build up large loads on the land surface. This is exacerbated by dry soil conditions, general windy conditions, and the agricultural and construction-related activities occurring at the outskirts of the Denver region.

When the thunderstorms do occur, the high kinetic energy associated with raindrop impact and overland flow carry the accumulated loads to the receiving waters. Data collected to date have shown that quantifiable relationships exist between the total amounts of rainfall, effective impervious areas, and storm loads for selected constituents. Unit area loading rates are greater for basins with a large extent of imperviousness which in general is related to more intense urban land use activities. The Cherry Creek basin, which encompasses the greater part of the rapidly developing downtown central business district, produces the most nonpoint pollution compared to other tributary basins on a per area basis. A good part of this basin is storm-sewered with direct hydraulic connections to the creek, which has a minimal base flow to begin with. The Cherry Creek basin can produce up to 25 percent of the total storm loads measured at a downstream location on the Platte even though it encompasses only 13 percent of the entire monitored area.

During late summer when streamflows are low and temperatures are high, there is not enough base flow in the South Platte to dilute the incoming storm loads. An order of magnitude increase, from around 300 to 3,000 cfs, will occur in the Platte and the runoff response of the basin to rainfall is rapid. It takes about two-tenths of an inch of rain to wet all the street and vegetated surfaces before runoff will occur. This is important because a large proportion of the total annual rainfall occurs as a number of these small rainfall amounts, or cloudbursts, added up together over the course of a year. Another consideration occurs during the month of May when the heaviest rainfall occurs (two to three inches of rain). This coincides with high streamflow in the South Platte River due to the snowpack in the mountains which is melting at this time of the year. A dilution effect can occur during this period. This does not occur during drought conditions as are prone to occur from time to time and which the region is now experiencing. Most of the urban runoff related problems can be considered to occur under conditions of low flow, high temperature and low dissolved oxygen observed during late summer which are critical periods for the survival of fish.

When discussing the urban runoff "problem" it is important to define what actually is meant by this term. It is not difficult to describe the "effect": that quantifiable loads of chemical constituents are generated during runoff events and that they move to receiving waters. Defining the "impact" is a much more difficult task. Intuitively the word impact refers to a condition adversely affecting public health or the health of aquatic biota, if the latter is determined to be a desirable amenity to preserve. Another consideration is that the magnitude of a water quality problem is defined in terms of how "clean" we choose a desirable level of water quality to be. Clearly, a "problem" occurs only when the criteria we have established has been exceeded more often than a predetermined "acceptable" number of times in a given period.

The duration of the exceedance is also important. The potential exists for a problem to occur when considering the fishery potential of a stream. The major contaminants of concern are potentially toxic substances. Besides the synthetic organic compounds, the dissolved forms of certain heavy metals, such as lead, zinc, and cadmium could pose a problem for stream life and also public water supply. This is because the dissolved metals are the biologically available form of the metal, the one which is easily incorporated into body tissues. Shock loading of water supply intakes from urban runoff is a potential concern and a management strategy designed to avoid using intake water with high dissolved metals would be advisable. At this point in our investigation, it would be difficult to assess the impact on stream organisms without an extensive literature review of toxicity levels impacting sensitive endemic fish species present. As the dissolved metal loads occur during the first part of storms and move as slug loads downstream, and considering durations on the order of a few hours of exposure and the tendency for fish to avoid plumes of toxic concentrations of dissolved substances, no conclusions can be drawn from the available data at this time on the extent or severity of the urban runoff impact on the South Platte River.

Even though it cannot be specified at this time if there is a chemical pollutant problem associated with urban runoff in Denver, another interpretation might connote that there is a physical problem. The effect of sedimentation in the stream channel must also be considered. Much of the sediment transported during runoff periods is clay-sized and remains suspended in the flow. This component merely moves through the system, whereas sand and silt are deposited in the river channel during storm periods, although scour of the bottom materials is also occurring. The impervious areas accumulate dry depositional materials which eventually are worked into the streams. Since major flood control structures have been built on the mainstem of the Platte and also on its major tributaries at the periphery of the urbanized Denver area, no large events are allowed to really scour the channel and both point source and nonpoint source sediments accumulate over time. These sediments have the potential to continually interact with the overlying water column depending on physical conditions of temperature, p^H and redox which control mobilization of heavy metals, for instance. Current thoughts are that keeping these materials out of the river might be beneficial in that the channel substrate would be improved, and thus, fish habitat. If the sediments are inactive then no chemical problem can be ascertained, however, a physical problem might still exist.

Other potential problems are evident from the storm data collected to date. Relatively high nutrient loads, mainly phosphorus and nitrogen compounds, have been observed to occur. The interpretation is that accelerated eutrophication of reservoirs, and other impoundments characteristic of water supply management in the semi-arid west, can and will occur in waterbodies receiving this nutrient-laden runoff. If the reservoir is used for agricultural irrigation purposes, then the nutrients might be considered beneficial, although the water-borne metals could be detrimental, especially when they accumulate in the soil over the years. If the reservoir is used for recreational purposes, then bacterial pollution might pose a problem as fecal material usually associated with the suspended matter can reach into the hundreds of thousands of colonies per 100 milliliters, far in excess of the suggested maximum of 2000 colonies/100 ml for secondary contact recreation. However, duration of exposure by humans could be effectively managed to minimize recreational disturbances.

The Best Management Practices, or BMPs, which were investigated in the Denver project include detention ponds and runoff ordinances. Although street sweeping with vacuum-type sweepers is a possible BMP, it was considered that this management practice would be very expensive. Other studies have shown negligible effect, negative effect, or beneficial effects from street sweeping. High sweeping frequency would probably preclude a cost-effective, energy-efficient approach. Sediment control, by detaining storm flows, has promise although maintenance of facilities is a continuing cost. Detention ponds built from scratch, retrofitted flood retention ponds already in place, and rock-filled percolation pits seem to hold promise as BMPs for the Denver region. Another alternative is the creation of wetlands in low-lying areas. The wildlife and aesthetic amenities, as well as natural high contaminant-removal efficiencies of wetlands should be seriously considered as well as negative impacts such as pest control. Results from monitoring a detention pond's effect on water quality are still being evaluated at the present time. As the water quality problem is merely changed into a solid waste problem, disposal of pond sediments in an appropriate manner must also be considered. Other considerations are the possible injuries which could be associated with these structures, and the delegation of maintenance responsibilities.

This brings us to the final considerations, those being the political and legal implications. There exists an intrinsic value to having a waterbody close by that people can enjoy, but assessing the dollar value ascribed to this is a difficult matter. Fish in the river are desirable, but at what replacement cost? What are the relative point and nonpoint effects on water quality, how can these be differentiated, how can available funding for control measure spending be determined on a cost-benefit basis? What flexibility exists for local governments to spend federal funds on nonpoint control? How is local financing generated? What political entities should be responsible for implementing a control program should one be established? Ultimately, what are the benefits to be accrued at what costs. Unfortunately, answers to these questions cannot be determined at this time for the Denver region, although they are being pursued and will be addressed in further analyses and deliberations on the matter.

NATIONWIDE URBAN RUNOFF PROGRAM
CASTRO VALLEY, CA
REGION IX, EPA

SUMMARY
SAN FRANCISCO BAY AREA NATIONAL URBAN RUNOFF PROJECT

by
Gary Shawley, Project Manager

I. PROJECT LOCATION

Castro Valley is a small, unincorporated community in Alameda County, California, within the metropolitan San Francisco Bay region. It is located on the east side of San Francisco Bay, south of Oakland and north of San Jose. The project's primary test area is a natural, 2.4 square mile watershed which is considered typical of residential basins in the San Francisco Bay region.

II. PROJECT DESCRIPTION

A. Runoff Related Problems

The San Francisco Bay-Delta Estuary is the single, most important water body in California. More than half of California's fishery resources either live in or directly depend on the estuary for their survival. It also provides recreation to over five million people who live near its shore.

Stormwater-borne pollutants are thought to adversely effect the water quality of San Francisco Bay, but a formal assessment of impacts is difficult because the Bay drainage area is so large (about 3200 square miles). Although runoff contributes large amounts of pollutants, its relationship to observed water quality problems remains uncertain. The primary use of many creeks in the Bay area is to convey stormwater runoff to the Bay. Castro Valley's creek's contribution of toxic pollutants into the Bay is seen as a potential water quality problem.

To determine whether improvements in water quality are necessary, requires one to consider the beneficial uses of the receiving water. In Castro Valley Creek, the support of aquatic habitat is an established beneficial use. Table 1 compares EPA's aquatic life criteria with the observed conditions in Castro Valley Creek for selected total and dissolved metals. The table reports concentrations but does not consider the annual loads delivered to the Bay. Note that the maximum dissolved concentrations are higher than the standards and that the total concentrations also exceed the maximum allowable concentrations.

TABLE 1

Concentrations* of Selected Metals in Castro Valley Creek Stormwater Compared to Water Quality Criteria for Aquatic Life

Constituent	Aquatic Life Criteria		Castro Valley Creek			
			Total		Dissolved	
	Maximum	Average	Max.	Average	Max.	Average
Copper	0.04	0.006	0.7	0.1	0.35	0.05
Lead	0.04	0.02	3.3	0.5	0.7	0.01
Zinc	0.6	0.05	2.2	0.3	0.7	0.1

*Units are mg/1, Castro Valley Creek water hardness = about 200 mg/1

Two additional problems in the Bay are thought to be linked to stormwater runoff:

- o Commercial and recreational shellfish harvesting is prohibited because of contamination from bacteria and heavy metals
- o Fish kill incidents can be traced to specific pollution causes (although many fish kills in the Bay occur for unknown reasons).

The state is investigating the causes of death of striped bass. The state may also initiate an aquatic habitat institute which will monitor the effects of point and non-point discharges on the bay biota.

The public's awareness of and concern for Castro Valley Creek's water quality is not high because its primary use (and that of most other creeks in the Bay area) is to convey stormwater runoff into San Francisco Bay. To the extent that it exists, public perception of a water quality problem focuses on the Bay as a scenic, recreational and commercial water resource for all communities within the Bay Area. There is widespread (and at times vocal) citizen concern over water quality of the Bay itself. The Bay area 208 Study drew heavily upon public support and active citizen participation in carrying out its problem identification tasks. However, the magnitude and technical/institutional complexity of Bay water quality problems tend to discourage remedial action by any one community.

B. Best Management Practice Investigated

This project was conducted to develop information on the control of urban stormwater runoff and the potential impacts on water quality. This was the first project to be part of EPA's Nationwide Urban Runoff Program (NURP) and was designed to develop an understanding of the relationship between street cleaning and urban stormwater runoff quality, using Castro Valley Creek as the focus. The scope of this project did not include an investigation of the effects of street cleaning on the water quality of San Francisco Bay. However, the project was based on the assumption that, if street cleaning would improve water quality in Castro Valley Creek, then street cleaning on a larger scale might improve water quality in the Bay.

1. Effectiveness

Information on the urban runoff mass loading was compared to the initial street surface loading values for each constituent. This analysis showed that up to 20 percent of the total solids and about 35 percent of the lead could have been prevented from reaching the creek. Figure 1 illustrates this relationship and further shows that, after about three passes per week, additional street cleaning effort is unproductive. If maximum urban stormwater runoff improvements are to result from street cleaning, then the streets should be cleaned during the winter months between adjacent storm periods in the Bay area.

2. Costs

Figure 2 shows that, after an initial steep rise in unit cost (i.e., from zero to twice-a-month street cleaning), the unit costs actually decrease. That is, the cost required to prevent a pound of material from reaching the receiving water decreases. After the frequency exceeds about three times per week, however, the unit costs increase again. If the program costs can be justified in terms of water quality, then cleaning three times a week between the winter storms may give the best return for the money for total solids.

3. Special Asbestos Study

As part of this project, a special study of asbestos was conducted and it yielded some interesting results. It was confirmed that optical techniques are inadequate to identify asbestos in small quantities, especially for small fiber sizes. Also, about 10 percent of the runoff monitored had detectable asbestos. The asbestos fiber concentration in urban runoff was about 30 million fibers per liter. This corresponds to 3×10^{13} fibers per acre per year for an area without asbestos in the natural soils. Eighty percent of the street surface samples had detectable asbestos fibers. Street cleaning was found capable of removing 10% of the asbestos on street surfaces with weekly cleaning and up to 50% with cleaning three times per week.

III. DESIGN OF STREET CLEANING PROGRAMS FOR WATER QUALITY

Procedures were developed to calculate the effectiveness of street cleaning operations in improving urban runoff quality. Simple tables and figures were prepared in the project report to supplement this discussion. These procedures can be used to develop street cleaning programs necessary to meet runoff allocation goals, the most cost-effective unit removal costs or just the appropriation of available street cleaning dollars in the service area. They can also be used to determine when and where service reductions should be made as decreasing budgets warrant.

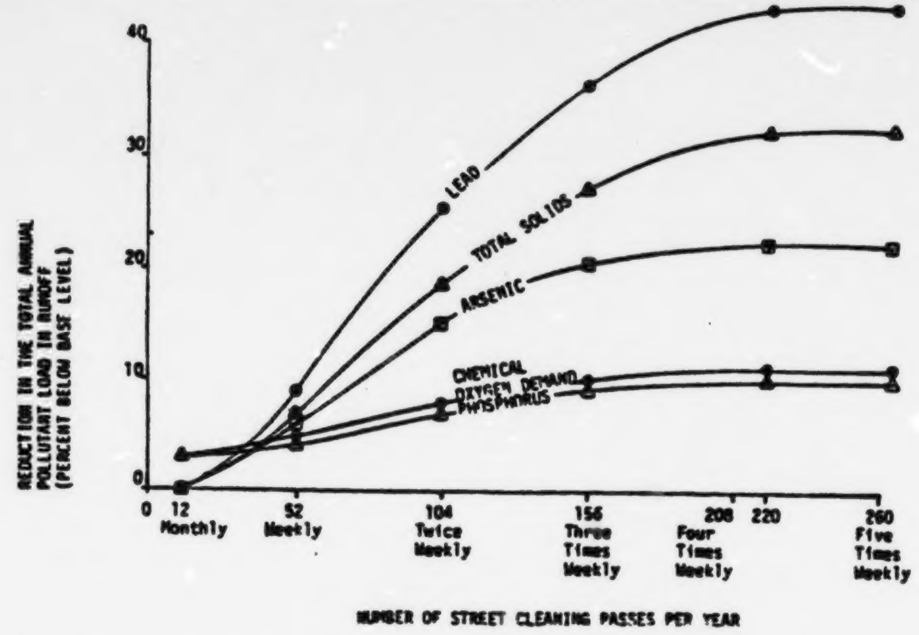


FIGURE 1. IMPROVEMENT IN URBAN RUNOFF QUALITY AS A FUNCTION OF STREET CLEANING EFFORT

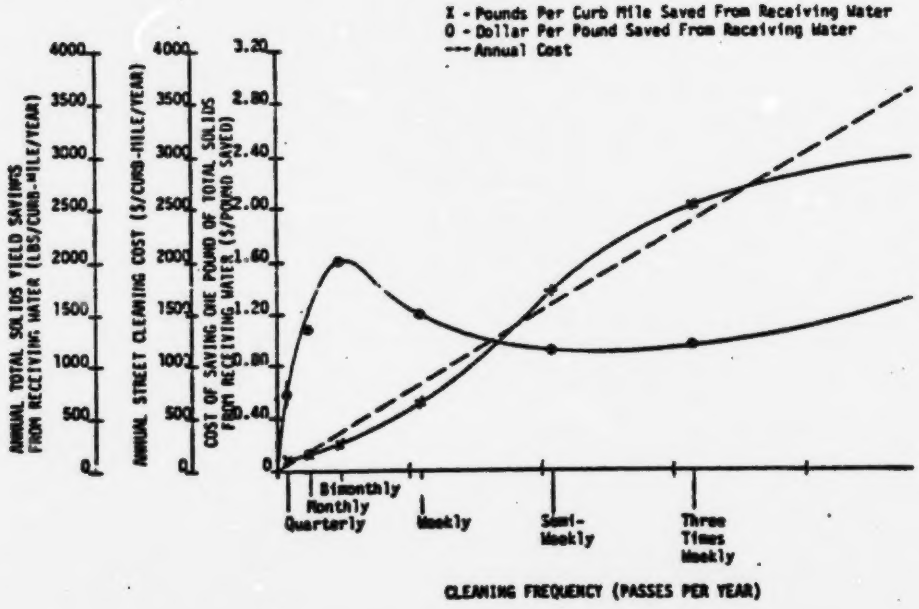


FIGURE 2. UNIT COST EFFECTIVENESS OF CONTROLLING URBAN RUNOFF TOTAL SOLIDS BY STREET CLEANING

NATIONWIDE URBAN RUNOFF PROGRAM

BELLEVUE, WA

REGION X, EPA

The Bellevue NURP project is located totally within the limits of the City of Bellevue, King County, Washington.

Project Description

The Bellevue drainage system relies on an extensive network of small streams as a "trunk system" to convey Storm and Surface Water to the two large lakes, Lake Washington and Lake Sammamish, bordering Bellevue to the west and east respectively. Major problems are solids and pollutant delivery into this natural conveyance system and erosion and flooding within the conveyance system. These problems occur at some level almost continuously during our seven-month winter rain season, with as many as half-a-dozen serious, significantly damaging events per year. There also have been sporadic fish kills due to accidental spills and some indiscriminant dumping. These problems have been documented as largely responsible for serious deterioration in fish habitat in the stream system.

Since the City's objective to manage the Storm and Surface Water System to operate naturally (according to natural principles), the City relies on pollutant source controls and regional and on-site detention as major controls. The management practices being evaluated in Bellevue are street sweeping, catchbasins and line maintenance, and detention. Surrey Downs and Lake Hills are two residential basins under study for street sweeping and conveyance maintenance. An urban arterial basin is being studied for detention as a water quality control.

Since the 1960's Bellevue has been very interested in water quantity and quality controls for its Storm and Surface Water System. Several public referenda have been held which resulted in the foundation of a Drainage Utility in the mid-1970's and the sale of $10 million in revenue bonds in the 1980's for major capital improvements. Strong public support has also resulted in stringent erosion control regulations and enforcement, a salmon enhancement program for Bellevue's streams, and participation in NURP. Bellevue volunteered, as part of a pilot program, to receive the first general NPDES permit in the State for stormwater discharges. Strong public and political backing have been an essential part of Bellevue's progress in stormwater management. Bellevue plans to develop a comprehensive storm water quality management program based on information generated through NURP.

Preliminary Results

Preliminary results indicate that street sweeping is not a effective measure for stormwater runoff pollution abatement in Bellevue. The best removals seen to date have been 30%-40% and these are rarely achieved. Even without street sweeping for a 5-7 month period, accumulation is usually no more than 500-800 lbs. solids/curb-mile in our experimental basins which is significantly cleaner than other areas monitored in the country. An intensive street sweeping program of three times a week using a standard mobil sweeper rarely reduces this load beyond 300-350 lbs. solids/curb-mile. During periods of low loading, negative removals have been frequently observed. This is probably due to erosion of the street surface and/or broom, or possibly to tracking in of material on the bottom of the sweeper from dirty areas.

One reason for the low loadings is probably climate. Rainfall in Bellevue occurs so frequently (approximately every two days in winter and every 4-7 days in summer) that before accumulation reaches a level where sweeping could be effective, rain effectively washes off the streets. In addition, the street sweepers do not operate well under continually damp street surface conditions.

Comparing street surface loads to storm loads, we have found that most of the sediment material is not coming from the streets. The only time street surface material contributes significantly to storm loads is for small storms (short duration, low intensity). For the larger storms, more off-street contribution and more conveyance-system bedload movement is indicated. We have also found that solids loads are seasonal, with up to 50% of the total annual solids loadings delivered in the months of November and December. These loads may be coming from erosion and/or washout of the systems bedload with the first heavy seasonal rains.

Investigation of catchbasins revealed sediment loads ranging from 0.5-2.5 $ft.^3$ catchbasin. This is greater than the street area contributary to these catchbasins but apparently little of this bedload moves once an "equilibrium" bedload has been established. It was also found that street surface and catchbasin sediment is comprised of similar constituents, possibly implying a similar source. The constituents observed in the runoff, however, are significantly different, possibly indicating different significant sources.

Preliminary Conclusions

In residential basins at least, street sweeping is probably of little value as a water quality control measure. Since this appears to be based primarily on area hydrology, street sweeping may be of little value in most areas (land uses) in Bellevue except where these are extremely high, instantaneous loads. We hope to evauate other land use areas to test this preliminary conclusion during the last phase of the project. If sweeping is useful at all, it probably would be in late summer and fall before the winter rains and before the salmon return to spawn in Bellevue's streams.

Catchbasin and sewer cleaning may have some impact but more data and modeling are needed. Specifically it's necessary to investigate whether, if bedloads were removed on a more frequent basis (just before when they reach equilibrium allowing re-accumulation), significant improvements in runoff quality would follow. The City hopes to test this hypothesis during the last phase of the project. The data to date have clearly shown that sediment should be target pollutant for control since most of the polluting material is associated with solids.

In the last stage of the study, Bellevue will be looking more closely for pollutant sources and controls not associated with streets. That portion of the study focussed on detention did not yield enough data to draw even preliminary conclusions at this time. However, detention has the potential for controlling both street and non-street pollutant sources, as well as water quantitiy problems. Several hundred of these systems are already installed in Bellevue. Therefore, Bellevue is very interested in the outcome of these studies.

APPENDIX F
PRIORITY POLLUTANT REPORT

APPENDIX F

FOREWORD

This appendix was prepared by the Monitoring and Data Support Division of the EPA Office of Water Regulations and Standards. Supporting contractors were Dalton-Dalton-Newport, Cleveland Ohio and Versar, Springfield, Virginia. Their preliminary findings of the NURP priority pollutant monitoring program and special metals sampling project are presented.

PRELIMINARY FINDINGS OF THE NURP PRIORITY POLLUTANT MONITORING PROGRAM

December 24, 1981

U.S. Environmental Protection Agency
Monitoring and Data Support Division
Mr. Rod Frederick, Project Officer
Dr. Richard Healy, Work Assignment Manager

CONTENTS

Page

List of Figures ii
List of Tables. iii
Preface iv

Section

1. Introduction 1

2. Methodology. 3

3. Findings 10

4. Conclusions. 23
    Potential Risk to Human Health. 26
    Potential Risk to Aquatic Life. 29

5. Special Metals Sampling Project. 31

References

Appendix

Appendix A - Land Use Characteristics of NURP Priority Pollutant Sites
Appendix B - Summary of EPA Ambient Water Quality Criteria
Appendix C - Pollutant Concentrations Reported in NURP Runoff Samples
Appendix D - EPA Water Quality Criteria and Standards for Toxic Metals
Appendix E - Special Metals Analytical Results
Appendix F - Special Metals Quality Control Data

FIGURES

Number Page

1 NURP Priority Pollutant City Locations . . . 5

2 NURP Special Metals City Location. 36

TABLES

1 NURP Cities Collecting Priority Pollutant Samples. 4

2 Summary of Analytical Chemistry Findings From NURP Priority Pollutant Samples 11

3 Priority Pollutants Not Detected in NURP Urban Runoff Samples 14

4 Most Frequently Detected Pollutants in NURP Urban Runoff Samples. 17

5 Summary of Water Quality Criteria Exceedances for Pollutants Detected in at Least 10 Percent of NURP Samples: Number of Individual Samples in Which Pollutant Concentrations Exceed Criteria. 18

5a Summary of Water Quality Criteria Exceedances for Pollutants Detected in at Least 10 Percent of NURP Samples: Percentage of Samples in Which Pollutant Concentrations Exceed Criteria 19

236

Number Page

6 Non-Priority Pollutants Reported in NURP Urban Runoff Samples 22

7 Predominant Sources of Priority Pollutants Which Have Been Detected in at Least 10 Percent of Urban Runoff Samples 24

8 Special Metals Project: Parameter List. . . 32

9 NURP Cities Participating in the Special Metals Sampling Project. 35

10 Summary of Analytical Procedures Used in the Special Metals Sampling Program. 37

11 Summary of Number of Detections, Mean Concentrations, Range and Detection Limits for Special Metals Data Collected as of October 1981 41

12 Summary of Water Quality Criteria Violations. 45

13a Total Recoverable and Dissolved Metals Concentration as a Percent of Total Metals Concentration: Priority Pollutant Metals 46

13b Total Recoverable and Dissolved Metals Concentration as a Percent of Total Metals Concentration: Non-Priority Pollutant Metals 47

14 Summary of Violations of EPA's "Red Book" Criteria for Non-Priority Pollutant Metals 49

PREFACE

The U.S. Environmental Protection Agency, Office of Water Regulations and Standards (OWRS), is conducting programs to evaluate the environmental hazards posed by priority pollutants in our nation's waters. The Monitoring and Data Support Division of OWRS is coordinating a program to determine the significance of urban runoff as one source of toxic pollutants to receiving waters. Specifically, the objective of this program, the Nationwide Urban Runoff Program (NURP) priority pollutant monitoring effort, is to make a preliminary assessment of which priority pollutants are found in urban stormwater runoff, how often, at what concentrations, and with what potential impacts.

The special metals sampling project is an additional effort designed to enhance the usefulness of the NURP priority pollutant data base for metals, which are the pollutants most frequently associated with urban stormwater runoff. The primary objective of the special metals project is to determine the relationships among dissolved, total, and total recoverable concentrations of selected metals in runoff waters.

The information developed through these efforts will permit identification of problem areas nationwide and the subsequent development of the most effective mitigation strategies to correct urban runoff related problems where necessary. This report documents the preliminary findings and results of the NURP priority pollutant and special metals monitoring projects as of October 1981.

SECTION 1

INTRODUCTION

The Nationwide Urban Runoff Program (NURP) priority pollutant monitoring effort was initiated to evaluate the significance of priority pollutants in urban stormwater runoff. The principal objectives of the program are (1) to determine which priority pollutants are found in urban stormwater runoff, how frequently, and at what concentrations, and (2) to evaluate the potential impacts of priority pollutants carried by urban runoff on aquatic life and water supplies. The information generated by this program will allow the Environmental Protection Agency's (EPA's) Office of Water Regulation and Standards (OWRS) to assess the significance of urban runoff relative to other point and non-point sources of toxic pollutants, in order to develop the most efficient and cost-effective control strategies.

The priority pollutants are a group of toxic chemicals or classes of chemicals listed under Section 307(a)(1) of the Clean Water Act of 1977 (PL 95-217, U.S.C. 466 et seq.). There are ten major groups of priority pollutants including 129 specific compounds or classes of compounds.

The NURP priority pollutant monitoring program was developed by EPA's Water Planning Division which provided grants to various urban localities for sample collection and laboratory analysis. EPA's Monitoring and Data Support Division (MDSD) is providing technical guidance concerning sampling and analysis procedures, quality assurance and quality control, processing of data, and interpretation of results. The NURP priority pollutant program was developed as a logical extension of the NURP conventional pollutant program, which is primarily concerned with measuring concentrations of conventional pollutants such as solids, phosphorus, nitrogen, and nitrates in urban runoff.

With priority pollutant sampling activities now well underway nationwide, this report presents preliminary results to date based on data which were available as of October 31, 1981, and offers some tentative conclusions regarding program objectives. Results are presented in such a way as to be usable by individuals whose concerns are national, regional, or local in scope. Obviously, these are not final conclusions, but observed trends in the data. Final conclusions must await completion, verification, and analysis of the final data base.

This report is organized as follows:

Section 2 - Methodology
Section 3 - Findings
Section 4 - Conclusions
Section 5 - Special metals project

SECTION 2

METHODOLOGY

Nineteen cities and metropolitan governmental councils (henceforth all will be referred to simply as "cities") are participating in the NURP priority pollutant monitoring program (Table 1). The geographical distribution of these cities includes 11 of the 18 major river basins in the continental United States (Figure 1), and ensures that a variety of climatic regimes and soil types are represented in the sample population. MDSD provided cities with the following general guidelines:

1. Use NURP sampling sites which are also being used for conventional pollutant sampling.
2. Use sites which have flow only when it rains.
3. Take a flow composite sample for the entire storm event. Discrete samples can also be taken to determine concentration variations during the storm event.

Early in the program, participating cities attended an MDSD-sponsored workshop in Springfield, Virginia. Using the sampling guidance manual as a guide ("Monitoring of

TABLE 1.

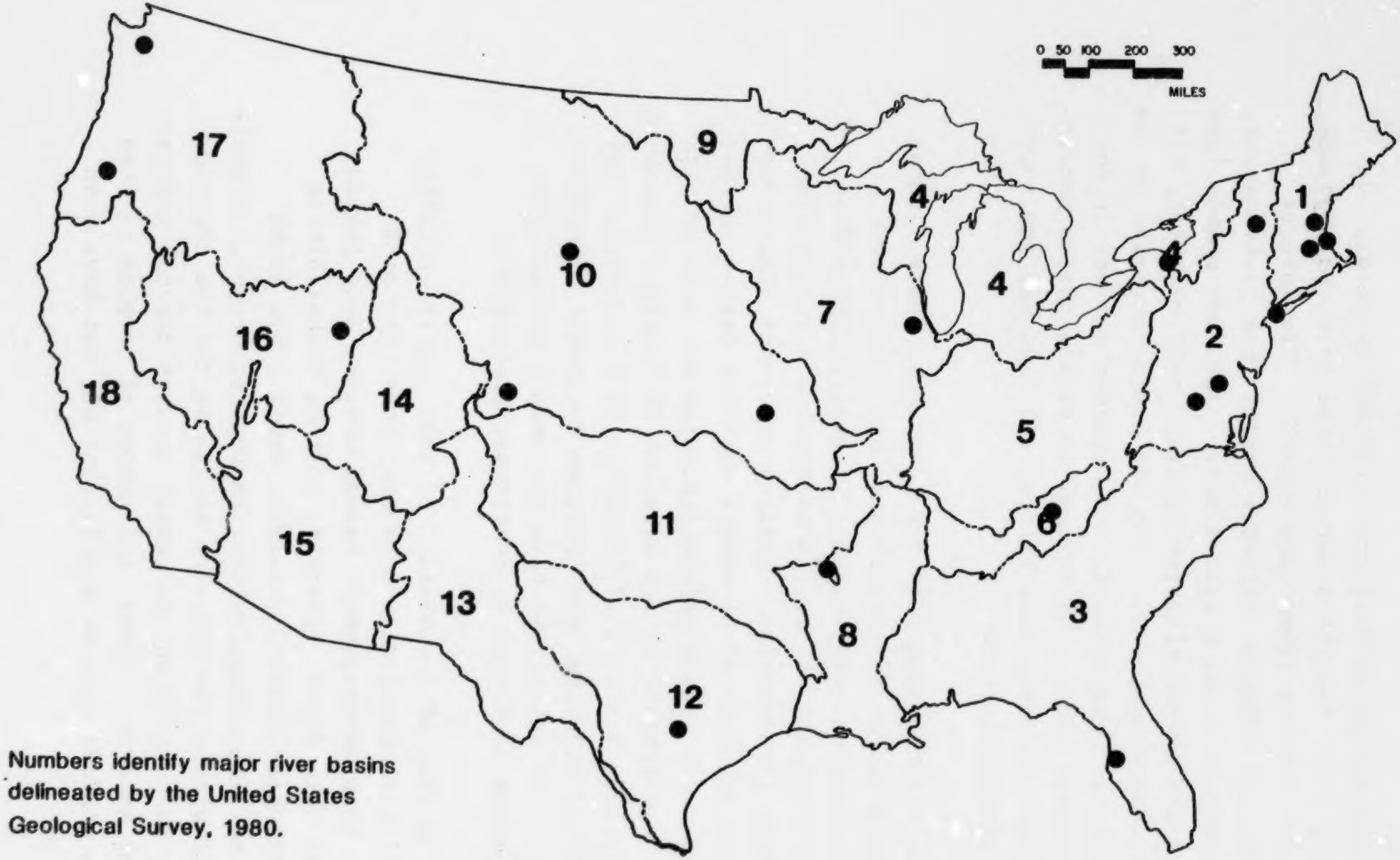
NURP CITIES
COLLECTING PRIORITY POLLUTANT SAMPLES[a]

1. Durham, New Hampshire
*2. Lake Quinsigamond, Massachusetts
3. Mystic River, Massachusetts
*4. Long Island, New York
5. Lake George, New York
6. Irondequoit Bay, New York
7. Metro Washington, D.C.
8. Baltimore, Maryland
11. Tampa, Florida
12. Knoxville, Tennessee
*17. Glen Ellyn, Illinois
*19. Austin, Texas
*20. Little Rock, Arkansas
21. Kansas City, Missouri
*22. Denver, Colorado
23. Salt Lake City, Utah
*24. Rapid City, South Dakota
*27. Bellevue, Washington
*28. Eugene, Oregon

* Asterisk indicates cities from which priority pollutant analytical data were available as of 10/31/81 in time to be included in this report.

[a] Numbering system conforms to NURP convention; some numbers are omitted as not all NURP cities are collecting priority pollutant samples.

Toxic Pollutants in Urban Runoff: A Guidance Manual" [Versar, 1980a]), a number of issues were covered, e.g., sample collection procedures such as container selection, container preparation, sample preservation, and shipping procedures; and modification of conventional sampling equipment for the collection of priority pollutant samples. Extensive information on NURP guidance regarding these and other relevant topics can be obtained from the many sources which are listed in the References section of this report.



Numbers identify major river basins delineated by the United States Geological Survey, 1980.

●: Priority Pollutant City

Figure 1. NURP Priority Pollutant City Locations.

Samples are being collected from approximately 70 catchments which include a varied range of sizes, populations, and land use types (Appendix A). The largest catchment, for example, collects runoff from 33,544 acres, the smallest from but a single acre. The most common land use types are low-density residential, medium-density residential, and commercial. Land use characteristics of the sampling sites were obtained and recorded for use in future analyses, which will attempt to relate toxics concentrations and loadings to site-specific land use and topographic characteristics.

Each participating city has made appropriate laboratory contracts for analytical services. Six cities arranged for such services through a central EPA office, while the remaining 13 cities contracted directly with independent laboratories. Quality assurance (QA) procedures were established to ensure that the data developed from these many cities and laboratories would be of high quality. QA procedures are detailed in "Quality Assurance for Laboratory Analysis of 129 Priority Pollutants," (Versar, 1980b), and other NURP program documents. Inasmuch as final QA/QC activities have not been completed, all data reported here must be considered preliminary.

At the time of preparation of this report, priority pollutant analytical data were available from nine cities: Lake Quinsigamond, Massachusetts; Long Island, New York; Glen Ellyn, Illinois; Austin, Texas; Little Rock, Arkansas; Denver, Colorado; Rapid City, South Dakota; Bellevue, Washington; and Eugene, Oregon. A maximum of 68 sample results were available for the organic priority pollutants and 46 sample results for the inorganics. For some pollutants, the number of samples is less than the maximum because a pollutant may not have been analyzed for in a particular sample or because some results were withdrawn for quality control reasons. The data available for this report represent approximately one half of the final data base expected.

For the purposes of this program, asbestos was not analyzed due to high associated costs. Dioxin was not specifically analyzed for because of the health risk to laboratory personnel involved. Gas chromatograms were scanned for the possible presence of dioxin, however.

The approach used to summarize and analyze the NURP priority pollutant data is outlined below:

1. A complete listing of the data was compiled for each pollutant which was detected, and identifies city, site, date of sample collection, whether the sample was discrete or composite, pH, and measured pollutant concentration (Appendix C). Important qualifying information concerning the analytical results was also noted.

2. Summaries of the data were prepared for each detected pollutant including range of detected concentrations, mean, number of samples, frequency of detection, and concentrations of that pollutant reported in other urban runoff studies.

3. For those priority pollutants detected in 10 percent or more of the samples, pollutant concentrations in each undiluted runoff sample were compared to EPA water quality criteria and drinking water standards (Appendix B). Such a comparison provided an initial identification of pollutants whose

concentrations in runoff could lead to potential violations of criteria or standards or adversely impact aquatic life or water supplies.

4. In a limited number of NURP samples, non-priority pollutants were also analyzed for and these results are reported. These non-priority pollutants are somewhat similar to priority pollutants in chemical form and should be considered for future work; however, specific analysis is beyond the scope of the current program.

With reference to the above, some clarification is worth noting. In Step 2, the geometric mean rather than the arithmetic mean is used, as this is the appropriate measure of central tendency when data are log-normally distributed. Such a distribution of NURP and similar data has been demonstrated in the draft EPA Water Planning Division report "Preliminary Results of the NURP Program" (Athayde et al., 1981), and other runoff studies.

Calculating an exact value for the mean (geometric or arithmetic) is impossible, however, when some results are "not detected" and therefore unquantified. What can be done in this case is to calculate two geometric means, which determine a range within which the actual mean should fall. The upper end of this range is calculated by substituting the reported (or nominal) detection limit in the case of an "undetected" result. The lower end is calculated by substituting one tenth of the detection limit (although in no case a value less than 0.001) for an undetectable result as a substitute for zero, which cannot be accommodated in geometric mean calculations. This range bracketing the geometric mean was not calculated if more than 85 percent of the sample results were "not detected," due to the preponderance of unknown values.

With regard to Step 3, several EPA water quality criteria were used. Criteria for the protection of aquatic life are of two types: (1) the freshwater "acute" criterion, the maximum concentration of a pollutant permitted at any time; and (2) the freshwater "chronic" criterion, the maximum 24-hour average concentration allowed. If either the acute or chronic criterion has not been established for a pollutant, then the lowest reported freshwater acute concentration or the lowest reported freshwater chronic concentration was substituted. Human health criteria include both a non-carcinogenic health criterion for the ingestion of contaminated water and organisms, and a carcinogenic effects criterion at the 10^{-5}, 10^{-6}, and 10^{-7} risk levels for ingestion of contaminated water and organisms. Human health criteria based on the ingestion of contaminated organisms only were not used, in order to apply the more stringent water and organisms standards. EPA also has criteria associated with taste and odor problems (organoleptic criteria) as well as drinking water standards under the Safe Drinking Water Act.

SECTION 3

FINDINGS

Detailed NURP priority pollutant analytical results including city and site where sample was collected, date of collection, discrete or composite sample, pH, and pollutant concentration can be found in Appendix C. Appendix C also lists, for each detected pollutant, the range of concentrations, geometric mean (if calculated), number of samples, frequency of detection, and reported concentrations in other studies. A concise summary of the currently available data base is presented in Table 2..

The findings derived from this preliminary NURP priority pollutant data base are:

1. Sixty-two priority pollutants were detected in urban runoff (Table 2); 65 were not found in any urban runoff samples (Table 3). (Asbestos is not included in the NURP program and results for dichloromethane are not yet available.)

2. Thirteen of the 14 inorganic priority pollutants were found in urban runoff. Most frequently detected were zinc, lead, copper, and arsenic which were found in 100, 93, 91, and 58 percent of the

TABLE 2.

SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS
FROM NURP PRIORITY POLLUTANT SAMPLES[a]
(includes information received through 10/31/81)

Pollutant	Cities where detected[b]	Frequency of detection (%)	Range of detected concentrations (μg/1)
I. PESTICIDES			
1. Acrolein	Not detected		
2. Aldrin	Not detected		
3. α-Hexachlorocyclohexane (α-BHC) (Alpha)	22, 27	25	0.0027-0.9
4. β-Hexachlorocyclohexane (β-BHC) (Beta)	Not detected		
5. γ-Hexachlorocyclohexane (γ-BHC) (Gamma) (Lindane)	22,27	11	0.002-0.9
6. δ-Hexachlorocyclohexane (δ-BHC) (Delta)	27	3	0.006-0.007
7. Chlordane	2	2	0.01
8. DDD	Not detected		
9. DDE	Not detected		
10. DDT	27	2	0.35
11. Dieldrin	27	3	0.008-0.1
12. α-Endosulfan (Alpha)	27	2	0.2
13. β-Endosulfan (Beta)	Not detected		
14. Endosulfan sulfate	Not detected		
15. Endrin	Not detected		
16. Endrin aldehyde	Not detected		
17. Heptachlor	Not detected		
18. Heptachlor epoxide	Not detected		
19. Isophorone	Not detected		
20. TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin)	Not detected		
21. Toxaphene	Not detected		
II. METALS AND INORGANICS			
22. Antimony	22	2	2
23. Arsenic	2,19,20,22,27	58	2-35
24. Asbestos	Not included in NURP program		
25. Beryllium	20	9	1-4
26. Cadmium	2,20,22,27	38	0.2-17
27. Chromium	2,17,20,27,28	45	2-61
28. Copper	2,17,19,20,22,27,28	91	11-110
29. Cyanides	4,19,22,27	31	2-33
30. Lead	2,17,19,20,22,27,28	93	37.6-445
31. Mercury	20,28	7	0.6-1.2
32. Nickel	2,20,22,27	44	5-270
33. Selenium	19,22	20	2-25
34. Silver	17,27	4	0.6-0.8
35. Thallium	Not detected		
36. Zinc	2,17,19,20,22,27,28	100	10-546
III. PCBs AND RELATED COMPOUNDS			
37. PCB-1016 (Aroclor 1016)	Not detected		
38. PCB-1221 (Aroclor 1221)	Not detected		
39. PCB-1232 (Aroclor 1232)	Not detected		
40. PCB-1242 (Aroclor 1242)	Not detected		
41. PCB-1248 (Aroclor 1248)	Not detected		
42. PCB-1254 (Aroclor 1254)	Not detected		
43. PCB-1260 (Aroclor 1260)	2	2	0.03
44. 2-Chloronaphthalene	Not detected		
IV. HALOGENATED ALIPHATICS			
45. Methane, bromo- (methyl bromide)	Not detected		
46. Methane, chloro- (methyl chloride)	Not detected		
47. Methane, dichloro- (methylene chloride)	Data not available		

d)

TABLE 2. (Continued)

Pollutant	Cities where detected[b]	Frequency of detection (%)	Range of detected concentrations (µg/l)
IV. HALOGENATED ALIPHATICS (Continued)			
48. Methane, chlorodibromo-	28	1	2
49. Methane, dichlorobromo-	28	1	2
50. Methane, tribromo- (bromoform)	28	1	1
51. Methane, trichloro- (chloroform)	4,17,20,27,28	24	0.2-8
52. Methane, tetrachloro- (carbon tetrachloride)	4,20,28	6	1-2
53. Methane, trichlorofluoro-[c]	2,4,24,28	9	0.58-27
54. Methane, dichlorodifluoro-[c] (Freon-12)	Not detected		
55. Ethane, chloro-	Not detected		
56. Ethane, 1,1-dichloro-	4,20,28	9	1-5
57. Ethane, 1,2-dichloro-	28	2	4
58. Ethane, 1,1,1-trichloro-	4,17,20,22,24,28	35	1-23
59. Ethane, 1,1,2-trichloro-	4,20,28	8	1-3
60. Ethane, 1,1,2,2-tetrachloro-	4,20	9	1-3
61. Ethane, hexachloro-	Not detected		
62. Ethene, chloro- (vinyl chloride)	Not detected		
63. Ethene, 1,1-dichloro-	28	3	1.5-4
64. Ethene, 1,2-trans-dichloro-	20,28	12	1-3
65. Ethene, trichloro-	4,20,28	12	1-3
66. Ethene, tetrachloro-	4,17,20,22,28	10	1-43
67. Propane, 1,2-dichloro-	28	1	3
68. Propene, 1,3-dichloro-	28	3	1-2
69. Butadiene, hexachloro-	Not detected		
70. Cyclopentadiene, hexachloro-	Not detected		
V. ETHERS			
71. Ether, bis(choromethyl)	Not detected		
72. Ether, bis(2-chloroethyl)	Not detected		
73. Ether, bis(2-chloroisopropyl)	Not detected		
74. Ether, 2-chloroethyl vinyl	Not detected		
75. Ether, 4-bromophenyl phenyl	Not detected		
76. Ether, 4-chlorophenyl phenyl	Not detected		
77. Bis(2-chloroethoxy) methane	Not detected		
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)			
78. Benzene	4,17,20,27,28	34	1-13
79. Benzene, chloro-	20,28	7	1-3
80. Benzene, 1,2-dichloro-	Not detected		
81. Benzene, 1,3-dichloro-	Not detected		
82. Benzene, 1,4-dichloro-	Not detected		
83. Benzene, 1,2,4-trichloro-	Not detected		
84. Benzene, hexachloro-	Not detected		
85. Benzene, ethyl-	4,17,20,28	12	1-3
86. Benzene, nitro-	Not detected		
87. Toluene	4,17,20,	24	3-9
88. Toluene, 2,4-dinitro-	Not detected		
89. Toluene, 2,6-dinitro	Not detected		
VII. PHENOLS AND CRESOLS			
90. Phenol	20,27	3	2-3
91. Phenol, 2-chloro-	20,28	3	2-22
92. Phenol, 2,4-dichloro-	22	1	10
93. Phenol, 2,4,6-trichloro-	Not detected		
94. Phenol, pentachloro-	4,19,20,22,27,28	18	1-115

(continued)

251

TABLE 2. (Continued)

Pollutant	Cities where detected[b]	Frequency of detection (%)	Range of detected concentrations (µg/l)
VII. PHENOLS AND CRESOLS (Continued)			
95. Phenol, 2-nitro-	Not detected		
96. Phenol, 4-nitro-	4,20,28	10	1-19
97. Phenol, 2,4-dinitro-	Not detected		
98. Phenol, 2,4-dimethyl-	Not detected		
99. m-Cresol, p-chloro-	4	4	1-2
100. o-Cresol, 4,6-dinitro-	Not detected		
VIII. PHTHALATE ESTERS			
101. Phthalate, dimethyl	Not detected		
102. Phthalate, diethyl	17,20	5	1-5
103. Phthalate, di-n-butyl	4,20,22,24,28	11	2.8-11
104. Phthalate, di-n-octyl	20	2	1
105. Phthalate, bis(2-ethylhexyl)	4,17,19,20,22,28	24	1-41.5
106. Phthalate, butyl benzyl	Not detected		
IX. POLYCYCLIC AROMATIC HYDROCARBONS			
107. Acenaphthene	Not detected		
108. Acenaphthylene	Not detected		
109. Anthracene	17,20,27	6	1-5
110. Benzo(a)anthracene	27	3	1-3
111. Benzo(b)fluoranthene	27	1	2
112. Benzo(k)fluoranthene	27	1	4
113. Benzo(g,h,i)perylene	Not detected		
114. Benzo(a)pyrene	27	3	1-2
115. Chrysene	17,27	6	0.6-4.5
116. Dibenzo(a,h)anthracene	Not detected		
117. Fluoranthene	17,27	7	0.3-12
118. Fluorene	Not detected		
119. Indeno(1,2,3-c,d)pyrene	Not detected		
120. Naphthalene	4,20,28	6	1-13
121. Phenanthrene	17,20,27	10	0.3-7
122. Pyrene	17,27	7	0.3-10
X. NITROSAMINES AND OTHER NITROGEN-CONTAINING COMPOUNDS			
123. Nitrosamine, dimethyl (DMN)	Not detected		
124. Nitrosamine, diphenyl	Not detected		
125. Nitrosamine, di-n-propyl	Not detected		
126. Benzidine	Not detected		
127. Benzidine, 3,3'-dichloro-	Not detected		
128. Hydrazine, 1,2-diphenyl-	Not detected		
129. Acrylonitrile	Not detected		

[a] Based on 68 organic and 46 inorganic sample results received as of 10/31/81, adjusted for preliminary quality control review. Nine cities reporting.

[b] Cities from which data are available:
2. Lake Quinsigamond, MA
4. Long Island, NY
17. Glen Ellyn, IL
19. Austin, TX
20. Little Rock, AR
22. Denver, CO
24. Rapid City, SD
27. Bellevue, WA
28. Eugene, OR
Numbering of cities conforms to NURP convention.

[c] Recently removed from priority pollutant list.

TABLE 3.

PRIORITY POLLUTANTS NOT DETECTED IN NURP URBAN RUNOFF SAMPLES[a]

(includes information received through 10/31/81)

Pollutant	Reported limits of detection[b] (µg/l)
I. PESTICIDES	
1. Acrolein	100
2. Aldrin	0.003-10
4. β-Hexachlorocyclohexane	0.004-10
8. DDD	0.012-10
9. DDE	0.006-10
13. β-Endosulfan	0.01-10
14. Endosulfan sulfate	0.03-10
15. Endrin	0.009-10
16. Endrin aldehyde	0.023-10
17. Heptachlor	0.002-10
18. Heptachlor epoxide	0.004-10
19. Isophorone	10
20. TCDD	0.5
21. Toxaphene	0.4-10
II. METALS AND INORGANICS	
35. Thallium	1-63
III. PCBs AND RELATED COMPOUNDS	
37. PCB-1016	0.04-10
38. PCB-1221	0.04-10
39. PCB-1232	0.04-10
40. PCB-1242	0.04-10
41. PCB-1248	0.05-10
42. PCB-1254	0.5-10
44. 2-Chloronaphthalene	10
IV. HALOGENATED ALIPHATICS	
45. Bromomethane	10
46. Chloromethane	10
54. Dichlorodifluoromethane[c]	10
55. Chloroethane	10
61. Hexachloroethane	10
62. Chloroethene	10
69. Hexachlorobutadiene	10
70. Hexachlorocyclopentadiene	10
V. ETHERS	
71. Bis(chloromethyl) ether	10
72. Bis(2-chloroethyl) ether	10
73. Bis(2-chloroisopropyl) ether	10
74. 2-Chloroethyl vinyl ether	1-10
75. 4-Bromophenyl phenyl ether	10
76. 4-Chlorophenyl phenyl ether	10
77. Bis(2-chloroethoxy) methane	10
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)	
80. 1,2-Dichlorobenzene	10
81. 1,3-Dichlorobenzene	10
82. 1,4-Dichlorobenzene	10
83. 1,2,4-Trichlorobenzene	10

(continued)

TABLE 3. (Continued)

Pollutant	Reported limits of detection[b] (μg/l)
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES) (Continued)	
84. Hexachlorobenzene	10
86. Nitrobenzene	10
88. 2,4-Dinitrotoluene	10
89. 2,6-Dinitrotoluene	10
VII. PHENOLS AND CRESOLS	
93. 2,4,6-Trichlorophenol	10-25
95. 2-Nitrophenol	10-25
97. 2,4-Dinitrophenol	25-250
98. 2,4-Dimethylphenol	10-25
100. 4,6-Dinitro-o-cresol	25-250
VII. PHTHALATE ESTERS	
101. Dimethyl phthalate	10
106. Butyl benzyl phthalate	10
IX. POLYCYCLIC AROMATICS	
107. Acenaphthene	10
108. Acenaphthylene	10
113. Benzo(g,h,i)perylene	10-25
116. Dibenzo(a,h)anthracene	10-25
118. Fluorene	10
119. Indeno(1,2,3-c,d)pyrene	10-25
X. NITROSAMINES AND OTHER NITROGEN-CONTAINING COMPOUNDS	
123. Dimethyl nitrosamine	10
124. Diphenyl nitrosamine	10
125. Di-n-propyl nitrosamine	10
126. Benzidine	100
127. 3,3'-Dichlorobenzidine	10
128. 1,2-Diphenylhydrazine	10
129. Acrylonitrile	100

[a] Based on 68 organic and 46 inorganic sample results received as of 10/31/81, adjusted for preliminary quality control review. Nine cities reporting.

[b] Where more than one detection limit is applicable because laboratory methodologies differed, a range is given.

[c] Recently removed from the priority pollutant list.

samples, respectively (Table 4). The maximum zinc concentration was 540 ug/l and the maximum lead concentration was 445 ug/l. Cadmium, chromium, cyanides, nickel, and selenium were detected in from 20 to 50 percent of the samples. Four metals (antimony, beryllium, mercury, and silver) were found in less than 10 percent of the samples. Thallium was the only priority pollutant metal never found.

3. Of the 113 priority pollutant organics (dichloromethane excluded), 49 were found in urban runoff. Of these, six were found in 20 percent or more of the NURP samples: α-hexachlorocyclohexane; trichloromethane (chloroform); 1,1,1-trichloroethane; benzene; toluene; and bis(2-ethylhexyl) phthalate. The maximum reported concentrations among these pollutants are 41.5 ug/l for bis(2-ethylhexyl) phthalate, 23 ug/l for 1,1,1-trichloroethane, and 13 ug/l for benzene. An additional nine organics were found in 10 to 19 percent of the samples (Table 4).

4. A comparison of individual sample pollutant concentrations undiluted by stream flow with EPA water quality criteria and drinking water standards reveals numerous exceedances of these levels, as shown in Tables 5 and 5a. Table 5 displays the exceedances on a number of samples basis, while Table 5a converts this information to a percentage basis. This analysis was conducted only for those pollutants detected in at least 10 percent of the samples. Among the metals, copper exceeded its freshwater acute criterion in 69 percent of the samples, while cadmium and lead each exceeded this criterion at least

TABLE 4.

MOST FREQUENTLY DETECTED POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[a]

(includes information received through 10/31/81)

Pollutants Detected in 50% or More of the NURP Samples

Inorganics	Organics
23. Arsenic (58%)	None
28. Copper (91%)	
30. Lead (93%)	
36. Zinc (100%)	

Pollutants Detected in 20% to 49% of the NURP Samples

Inorganics	Organics
26. Cadmium (38%)	3. α-Hexachlorocyclohexane (25%)
27. Chromium (45%)	51. Trichloromethane (Chloroform) (24%)
29. Cyanides (31%)	58. 1,1,1-Trichloroethane (35%)
32. Nickel (44%)	78. Benzene (34%)
33. Selenium (20%)	87. Toluene (24%)
	105. Bis(2-ethylhexyl) phthalate (24%)

Pollutants Detected in 10% to 19% of the NURP Samples

Inorganics	Organics
None	5. γ-Hexachlorocyclohexane (Lindane) (11%)
	64. 1,2-trans-Dichloroethene (12%)
	65. Trichloroethene (12%)
	66. Tetrachloroethene (10%)
	85. Ethylbenzene (12%)
	94. Pentachlorophenol (18%)
	96. 4-Nitrophenol (10%)
	103. Di-n-butyl phthalate (11%)
	121. Phenanthrene (10%)

---

[a] Based on 68 organic and 46 inorganic sample results received as of 10/31/81, adjusted for preliminary quality control review. Nine cities reporting. Does not include special metals samples.

TABLE 5.

SUMMARY OF WATER QUALITY CRITERIA EXCEEDANCES FOR POLLUTANTS DETECTED IN AT LEAST 10 PERCENT OF NURP SAMPLES: NUMBER OF INDIVIDUAL SAMPLES IN WHICH POLLUTANT CONCENTRATIONS EXCEED CRITERIA[a]

Pollutant	Number of times detected/Number of samples	Criteria exceedances[b]						
		None	FA	FC	OL	HH	HC[c]	DW
I. PESTICIDES								
3. α-Hexachlorocyclohexane	16/64						1,13,16	
5. γ-Hexachlorocyclohexane (Lindane)	7/64			1			1,2,7	
II. METALS AND INORGANICS								
23. Arsenic	26/45						26,26,26	
26. Cadmium[d]	17/45		9	17		2		2
27. Chromium[d,e]	20/44			1*				1
28. Copper[d]	41/45		31	41				
29. Cyanides	10/32			9				
30. Lead[d]	40/43		16	40		37		37
32. Nickel[d]	20/45			8		18		
33. Selenium	9/45					7		7
36. Zinc[d]	45/45		6	40				
IV. HALOGENATED ALIPHATICS								
51. Methane, trichloro- (chloroform)	16/66						8,16,16	
58. Ethane, 1,1,1-trichloro-	23/66	X						
64. Ethene, 1,2-trans-dichloro-	8/66	X						
65. Ethene, trichloro-	8/66						0,1,8	
66. Ethene, tetrachloro-	7/66						4,7,7	
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)								
78. Benzene	22/65						2,22,22	
85. Benzene, ethyl-	8/67	X						
87. Toluene	13/55	X						
VII. PHENOLS AND CRESOLS								
94. Phenol, pentachloro-	12/67		1*	7*	1			
96. Phenol, 4-nitro-	7/67	X						
VIII. PHTHALATE ESTERS								
103. Phthalate, di-n-butyl	7/61			6*				
105. Phthalate, bis(2-ethylhexyl)	14/59			13*				
IX. POLYCYCLIC AROMATIC HYDROCARBONS								
121. Phenanthrene	7/67						7,7,7	

* Indicates FTA or FTC value substituted where FA or FC criterion not available (see below).

[a] Based on 68 organic and 46 inorganic sample results received as of 10/31/81, adjusted for preliminary quality control review. Nine cities reporting.

[b] FA = Freshwater ambient 24-hour instantaneous maximum criterion ("acute" criterion).
FC = Freshwater ambient 24-hour average criterion ("chronic" criterion).
FTA = Lowest reported freshwater acute toxic concentration. (Used only when FA is not available.)
FTC = Lowest reported freshwater chronic toxic concentration. (Used only when FC is not available.)
OL = Taste and odor (organoleptic) criterion.
HH = Non-carcinogenic human health criterion for ingestion of contaminated water and organisms.
HC = Protection of human health from carcinogenic effects for ingestion of contaminated water and organisms.
DW = Primary drinking water criterion.

[c] Entries in this column indicate exceedances of the human carcinogen value at the 10^{-5}, 10^{-6}, and 10^{-7} risk level, respectively. The numbers are cumulative, i.e., all 10^{-5} exceedances are included in 10^{-6} exceedances, and all 10^{-6} exceedances are included in 10^{-7} exceedances.

[d] Where hardness dependent, hardness of 100 mg/l $CaCO_3$ equivalent assumed.

[e] Different sets of criteria are written for the trivalent and hexavalent forms of chromium. For purposes of this analysis, all chromium is assumed to be in the trivalent form.

TABLE 5a.

SUMMARY OF WATER QUALITY CRITERIA EXCEEDANCES FOR POLLUTANTS DETECTED IN AT LEAST 10 PERCENT OF NURP SAMPLES: PERCENTAGE OF SAMPLES IN WHICH POLLUTANT CONCENTRATIONS EXCEED CRITERIA[a]

Pollutant	Frequency of detection (%)	Criteria exceedances (%)[b] None	FA	FC	OL	HH	HC[c]	DW
I. PESTICIDES								
3. α-Hexachlorocyclohexane	25						2,20,25	
5. γ-Hexachlorocyclohexane (Lindane)	11			2			2,3,11	
II. METALS AND INORGANICS								
23. Arsenic	58						58,58,58	
26. Cadmium[d]	38		20	38		4		4
27. Chromium[d,e]	45			2*				2
28. Copper[d]	91		69	91				
29. Cyanides	31			28				
30. Lead[d]	93		37	93		86		86
32. Nickel[d]	44			18		40		
33. Selenium	20					16		16
36. Zinc[d]	100		13	89				
IV. HALOGENATED ALIPHATICS								
51. Methane, trichloro- (chloroform)	24						12,24,24	
58. Ethane, 1,1,1-trichloro-	35	X						
64. Ethene, 1,2-*trans*-dichloro-	12	X						
65. Ethene, trichloro-	12						0,1,12	
66. Ethene, tetrachloro-	22						6,22,22	
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)								
78. Benzene	34	X					3,34,34	
85. Benzene, ethyl-	12	X						
87. Toluene	24	X						
VII. PHENOLS AND CRESOLS								
94. Phenol, pentachloro-	18		1*	10*	1			
96. Phenol, 4-nitro-	10	X						
VIII. PHTHALATE ESTERS								
103. Phthalate, di-n-butyl	11			10*				
105. Phthalate, bis(2-ethylhexyl)	24			22*				
IX. POLYCYCLIC AROMATIC HYDROCARBONS								
121. Phenanthrene	10						10,10,10	

* Indicates FTA or FTC value substituted where FA or FC criterion not available (see below).

[a] Based on 68 organic and 46 inorganic sample results received as of 10/31/81, adjusted for preliminary quality control review. Nine cities reporting.

[b] FA = Freshwater ambient 24-hour instantaneous maximum criterion ("acute" criterion).
FC = Freshwater ambient 24-hour average criterion ("chronic" criterion).
FTA = Lowest reported freshwater acute toxic concentration. (Used only when FA is not available.)
FTC = Lowest reported freshwater chronic toxic concentration. (Used only when FC is not available.)
OL = Taste and odor (organoleptic) criterion.
HH = Non-carcinogenic human health criterion for ingestion of contaminated water and organisms.
HC = Protection of human health from carcinogenic effects for ingestion of contaminated water and organisms.
DW = Primary drinking water criterion.

[c] Entries in this column indicate exceedances of the human carcinogen value at the 10^{-5}, 10^{-6}, and 10^{-7} risk level, respectively. The numbers are cumulative, i.e., all 10^{-5} exceedances are included in 10^{-6} exceedances, and all 10^{-6} exceedances are included in 10^{-7} exceedances.

[d] Where hardness dependent, hardness of 100 mg/l $CaCO_3$ equivalent assumed.

[e] Different sets of criteria are written for the trivalent and hexavalent forms of chromium. For purposes of this analysis, all chromium is assumed to be in the trivalent form.

20 percent of the time. Freshwater chronic criteria exceedances were observed for lead, copper, and zinc in at least 89 percent of the samples. Drinking water criteria exceedances were significant for lead (86 percent of the time). For the non-carcinogenic human health criterion, lead (86 percent) and nickel (40 percent) exceedances were most frequent. Arsenic human carcinogenic criteria (at all risk levels) were exceeded 58 percent of the time; however, drinking water standards of 50 ug/l for this pollutant were not exceeded. (In cases where inorganic criteria values are water hardness dependent, a value of 100 mg/l $CaCO_3$ equivalent was assumed.)

5. Among the organics, criteria exceedances occurred most frequently in the freshwater chronic and human carcinogenic categories. Freshwater chronic exceedances (utilizing the lowest reported freshwater chronic toxic concentration) were observed most often for pentachlorophenol (10 percent), di-n-butyl phthalate (10 percent), and bis(2-ethylhexyl) phthalate (22 percent). Carcinogenic criteria exceedances at the 10^{-5} risk level were observed for α-BHC (2 percent), trichloromethane (12 percent), tetrachloroethene (6 percent), and benzene (3 percent). However, at the 10^{-7} risk level these exceedances increase to 25, 24, 22, and 34 percent, respectively. These exceedances at the 10^{-7} level occurred for every sample in which the pollutant was detected, a result of the fact that the carcinogenic criteria levels are less than the limits of detection which were used. For organics, the freshwater acute and organoleptic criteria were exceeded only by a single pentachlorophenol sample.

Whenever a criteria exceedance is noted above, this does not necessarily imply that actual violations of criteria did or will take place in receiving waters. Rather, the technique used is an initial screening procedure, to make a preliminary identification of those pollutants whose presence in urban runoff requires further study. Exceedances of freshwater chronic criteria levels may not persist for a full 24-hour period, for example. However, many small urban streams probably carry only slightly diluted runoff following storms, and acute criteria or other exceedances may in fact be real for such streams.

While the 65 priority pollutants not detected are of less immediate concern than those pollutants found often, they cannot safely be eliminated from all future consideration. Many of the pollutants not detected have criteria which are below the detection limits of routine analytical methods. More sensitive analytical methodologies must be used and dilution effects considered before it can be said with assurance that these pollutants are not found in urban stormwater runoff at levels which pose a threat to human health or aquatic life.

Several non-priority pollutants were reported by the laboratory analyzing the Denver runoff samples (Table 6). For example, the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) was found at a concentration of 180 ug/l, a level which violates its drinking water standard of 100 ug/l. The Denver results indicate that many toxic compounds which are not priority pollutants may be found in runoff, and that such compounds may require further investigation and control at some time in the future.

260

TABLE 6.

NON-PRIORITY POLLUTANTS REPORTED IN NURP URBAN RUNOFF SAMPLES

Pollutant	Estimated concentration (µg/l)	Number of times detected/Number of samples
6-Methoxy-N,N'-bis(1-methylethyl)-1,3,5-triazine-2,4-dione	64	1/7
4-Propoxyphenol	8	1/7
Methylheptanol	12	1/7
3-Methyl-2-cyclohexen-1-one	6-9	4/7
1-(2-Butoxyethoxy)ethanol	5-23	2/7
2,2,4-Trimethyl-1,3-pentanediol	17	1/7
Tributylphosphate	6	1/7
9,10-Anthracenedione or 9,10-Phenanthrenedione	20-29	2/7
2,4-Dichlorophenoxyacetic acid or 2,4-D	180	1/7
(1,1'-biphenyl)-carboxaldehyde	17	1/7
Unidentified substituted alkyl hydrocarbon	5-37	3/7
Unidentified substituted alkyl hydrocarbon	12-390	2/7
Unidentified substituted alkyl hydrocarbon oil	10-500	2/7
Unidentified substituted polycyclic aromatic	22	1/7
2,/2-(2-Butoxyethoxy)ethoxy/ethanol	8	1/7

Note: Results reported by the Denver NURP program.

SECTION 4

CONCLUSIONS

Section 3 identified the inorganic and organic priority pollutants which were most frequently detected in urban runoff and which were found at undiluted concentrations exceeding applicable water quality criteria and standards.* The 24 pollutants (9 inorganics and 15 organics) detected in greater than 10 percent of the urban runoff samples have been selected for further evaluation and discussion in this section. A cutoff point of 10 percent was used because the data are preliminary and the cutoff tends to minimize unusual runoff conditions. More pollutants will be analyzed in future reports.

The 24 priority pollutants found in 10 percent or more of the NURP samples, and their predominant sources, are shown in Table 7. In general, priority pollutant inorganics were found more frequently and at higher concentrations than the priority pollutant organics. The inorganics found most frequently and at the highest concentrations were arsenic, cadmium, chromium, copper, cyanide, lead, nickel, and zinc. Predominant sources of these metals in runoff are thought to be fossil fuel and gasoline consumption, metal alloy corrosion, and automobile tire wear. Lindane (γ-BHC), α-BHC, chloroform, 1,1,1-

*All findings and conclusions are considered tentative until completion of thorough quality assurance review.

TABLE 7.

PREDOMINANT SOURCES OF PRIORITY POLLUTANTS WHICH HAVE BEEN DETECTED IN AT LEAST 10 PERCENT OF URBAN RUNOFF SAMPLES

Pollutant		Predominant sources
		a. Fossil Fuels Combustion
121.	Phenanthrene	Product of the incomplete combustion of fossil fuels, especially wood and coal burned in residential home heating units.
23.	Arsenic	Products of fossil fuel combustion.
32.	Nickel	
		b. Gasoline Consumption
30.	Lead	Components of gasoline
78.	Benzene	
85.	Ethylbenzene	
87.	Toluene	
96.	4-Nitrophenol	
29.	Cyanide	Product of gasoline combustion
		c. Metal Alloy Corrosion
26.	Cadmium	Metals released from the corrosion of alloys and from electroplating wastes.
27.	Chromium	
28.	Copper	Metal released from the corrosion of copper plumbing and from electroplating wastes. Copper is also commonly used in algicides.
		d. Automobile Related Activities
29.	Cyanide	Anti-caking ingredient in road salts.
36.	Zinc	Component of automobile tires and a common ingredient in road salt.
51.	Chloroform	Product of a chemical interaction among road salt, gasoline, and asphalt.

(continued)

TABLE 7. (Continued)

Pollutant	Predominant Sources
	e. Pesticide Use
3. α-BHC 5. γ-BHC (Lindane)	Compounds commonly used in soil treatment to eliminate nematodes and other pests.
94. Pentachlorophenol	Primarily used to protect wood products from microbial and fungal decay. Telephone poles are commonly treated with pentachlorophenol, for example.
	f. Solvent Use by Light Industry
58. 1,1,1-Trichloroethane 64. 1,2-trans-Dichloroethene 65. Trichloroethene 66. Tetrachloroethene	Products used in solvents by light industries (e.g., dry cleaning, auto repair, paint contractors, metal finishing and degreasing) to dissolve grease and clean parts. The "spent" solvent typically finds its way into drains, open storm drains, and surface runoff due to careless disposal practices.
	g. Plastic Product Consumption
103. Di-n-butyl phthalate 105. Bis(2-ethylhexyl) phthalate	Two of the most widely used plasticizers (components which make plastic flexible). They find their way into urban runoff because, through time, they "leach" from numerous plastic products (e.g., garden hose, floor tile, plastic containers, food packaging) in which they are found.
	h. Natural Erosion
33. Selenium	Element which occurs naturally in rocks and soil.
	i. Chlorination of Drinking Water and Municipal Wastewater
51. Chloroform	Chemical compound formed as a result of the chlorination of drinking water and wastewater.

trichloroethane, benzene, toluene, bis(2-ethylhexyl) phthalate, phenanthrene, and pentachlorophenol were the priority pollutant organics found most frequently and at highest concentrations. Their predominant sources are believed to be pesticides, solvents, plastic products, and water chlorination practices.

POTENTIAL RISK TO HUMAN HEALTH

A comparison of undiluted NURP priority pollutant concentrations with EPA's human health criteria for water revealed that the organic priority pollutants found most frequently pose little risk to humans at detected levels, except possibly for phenanthrene and chloroform. Ten percent of the urban runoff samples for these two pollutants contained concentrations greater than the EPA criteria for protection of health from carcinogenesis at a 10^{-5} risk level. Pentachlorophenol (PCP) exceeded the organoleptic criterion in one sample, although it was found in 18 percent of the samples. PCP does not appear to be a carcinogen, but tests with rats have shown it to be teratogenic and fetotoxic.

Additional dilution during storm events may reduce the concentrations of the organic pollutants found from the levels measured in runoff. This, in addition to known fates and pathways of these organic pollutants, suggests a minimal risk to humans due to urban runoff-borne priority pollutants. Chloroform, solvents, and gasoline-related organics found in urban runoff are rather volatile (half-life 30 minutes) and are not expected to persist in surface waters. These compounds can be expected to persist in groundwater, however, where they are not able to volatilize.

PCP has a short lifetime in water because photolysis degrades it in streams within approximately one week. However, where conditions such as turbidity limit photolysis, degradation may take as long as several months. PCP also sorbs to sediments where it can persist for months and eventually recontaminate the water column, which can be a problem in streams that are attempting to recover from intermittent or continuous discharges. Phenanthrene is also readily adsorbed to sediments where it can persist and recontaminate the water column. The effect of remobilization of these pollutants from sediments must be further evaluated before a conclusion regarding potential risk to human health can be fully stated. If PCP and phenanthrene are found in additional NURP samples at concentrations of concern, monitoring may be recommended at nearby water supplies.

The predominant pathway for human exposure for the organics associated with gasoline is through ingested food and inhalation. Contaminated surface water should therefore pose little risk at the levels measured in NURP samples. The plasticizers and pesticides should also pose a minimal threat to humans as contaminated surface water is an insignificant exposure pathway for these chemicals. The plasticizer values in urban runoff are orders of magnitude below toxic levels. However, bis(2-ethylhexyl) phthalate has been shown to accumulate in aquatic life and sediments. The effects of exposure to humans due to these pathways at measured concentrations are currently unknown.

Some of the priority pollutant metals found in urban runoff could represent a potential risk to human health. Exceedances of the non-carcinogenic human health, drinking water, and human carcinogenic criteria were observed. Detected lead concentrations in undiluted runoff ranged from 38 to 445 ug/l and exceeded the drinking water standard and human health criterion of 50 ug/l (total lead) in 86 percent of the samples. Selenium concentrations in undiluted runoff of from 2 to 25 ug/l exceeded the drinking water standard and human health criterion of 10 ug/l (total selenium) in 16 percent of the samples. Although dilution in receiving streams and subsequent treatment in drinking water treatment facilities would likely reduce these observed concentrations, drinking water standard violations are still possible under worst case conditions. Such conditions would include cases where: (1) the runoff generated during a storm event represented a large portion of the total receiving water flow, resulting in a dilution of less than 1 to 10; (2) the preliminary sampling results are representative of lead and selenium concentrations above drinking water supply intakes; and (3) lead and selenium removal by public drinking water treatment facilities is minimal. Specific risks to drinking water supplies could be evaluated by confirmatory sampling during storm events.

Nickel concentrations in undiluted runoff were found to exceed the human health criterion of 13.4 ug/l (total nickel) in 40 percent of the samples with detected total nickel concentrations ranging from 5 to 270 ug/l. Violations are expected to be less than the 40 percent figure after dilution by receiving streams. Moreover, nickel is not considered a significant human health problem in water because it is poorly absorbed by the body when ingested. Inhalation of nickel, especially nickel carbonyl, poses the greatest risk to human health. However, nickel compounds are suspected of acting synergistically with some carcinogens to increase mutagenic effects (Sunderman, 1981).

Arsenic concentrations in undiluted runoff frequently exceeded the EPA human carcinogenic criteria (10^{-5} risk level) of .022 ug/l. There is, however, presently a debate on the carcinogenic potency of arsenic, and this precludes a meaningful assessment of the risk to humans at this time. The arsenic levels in the undiluted runoff were all below the 50 ug/l EPA drinking water standard.

POTENTIAL RISK TO AQUATIC LIFE

Only one organic priority pollutant, pentachlorophenol, was found to exceed freshwater acute aquatic life criteria. This occurred only once, although the compound was detected in 12 out of 67 NURP samples.

Four priority pollutant metals, cadmium, copper, lead, and zinc, exceeded acute criteria in 13 to 68 percent of the samples. The highest detected values for these pollutants were two to five times higher than their appropriate criteria. Consequently, these pollutants could cause harm to aquatic life, depending upon receiving stream dilution.

These same four priority pollutant metals, plus nickel and cyanide, also exceeded 24-hour freshwater chronic criteria in 18 to 93 percent of the samples. The highest detected values for these pollutants ranged from 3 to 680 times higher than their appropriate criteria. However, attenuating circumstances such as dilution and storm duration must be taken into account in order to fully evaluate the significance of these exceedances. Since most storms last between 2 and 16 hours, violations of chronic criteria levels appear to be unlikely. The long-term effects on aquatic life of these pollutants bound to sediments, however, are unknown. These six pollutants may accumulate to some degree in sediments.

One final observation can be made regarding toxic metal problems in runoff and receiving stream waters. Many metals appear to be bound to organic matter or mineral particulates in water or bottom sediments. Through desorbtion they are potentially available for movement in a soluble form into the water column. In many cases desorbtion is governed by the physical-chemical parameters of pH, oxidation-reduction potential (EH), and dissolved oxygen (DO). Low (acid) pH, EH, and DO favor solubility. Current research on acid precipitation suggests that the pH and possibly the EH of stormwater in many locations is decreasing. Consequently, an increase in the concentration of soluble metals and therefore the toxicity of these pollutants in the water might be expected.

SECTION 5

SPECIAL METALS SAMPLING PROJECT

INTRODUCTION

The Special Metals Project was initiated to enhance the usefulness of the NURP priority pollutant metals data base and to provide additional perspective on the potential toxicity of priority pollutant metals in urban runoff. The primary objective of this project was to determine the relationship among dissolved, total, and total recoverable concentrations of 29 metals (Table 8), including both priority and non-priority pollutant metals, and to evaluate the potential impact of priority pollutant metals in urban runoff on aquatic life and water supplies. A secondary objective was to ensure a high level of quality in the generated data by having all the metal analysis conducted at a single laboratory. This project, therefore, expands the NURP priority pollutant metals data base which provides results for only one form (or fraction) of each metal's concentration, and which uses numerous laboratories.

Definitions of the three metal fractions analyzed in this project are given below:

- Dissolved metals - those constituents (metals) which will pass through a 0.45 micron membrane filter. Occasionally referred to as "soluble" metal content.
- Total recoverable metals - the concentration of metals in an unfiltered sample following treatment with hot dilute mineral acid. Occasionally referred to as "extractable" metal content.
- Total metals - the concentration of metals determined in an unfiltered sample following vigorous digestion with concentrated nitric acid.

Table 8

Special Metals Project: Parameter List

Priority Pollutant Metals	Non-Priority Pollutant Metals
Arsenic (As)	Aluminum (Al)
Beryllium (Be)	Barium (Ba)
Cadmium (Cd)	Boron (B)
Chromium (Cr)	Calcium (Ca)
Copper (Cu)	Cobalt (Co)
Lead (Pb)	Iron (Fe)
Mercury (Hg)	Lithium (Li)
Nickel (Ni)	Magnesium (Mg)
Selenium (Se)	Manganese (Mn)
Silver (Ag)	Molybdenum (Mo)
Thallium (Tl)	Potassium (K)
Zinc (Zn)	Sodium (Na)
	Strontium (Sr)
	Tin (Sn)
	Titanium (Ti)
	Vanadium (V)
	Yttrium (Y)

The three forms of metal are identified and quantified because: (1) in most cases, aquatic life toxicity is believed to be directly related to the amount of dissolved metal available, and (2) total recoverable and total metals results are directly comparable to EPA water quality criteria and drinking water standards, respectively (Appendix D). Although the dissolved metal fraction is most directly related to toxicity, criteria and standards are based on total metals fractions because they provide an indication of the amount of metal available for dissolution. EPA's 1980 water quality criteria for priority pollutant metals are based on laboratory toxicity tests in which the actual form of the metal as measured in concentration may not be known with certainty; most of these tests were probably conducted using metals in the more toxic, dissolved form. The criteria for metals, however, are expressed in terms of total recoverable metal in an effort to provide adequate protection of aquatic life. This fraction was selected as the basis for the criteria because: (1) the actual form of the metal reported in laboratory toxicity tests may not be known, and (2) metals in the aquatic environment may undergo reactions which convert various forms of the metal into the dissolved fraction. EPA's drinking water standards, however, are based on the total metals fraction. Consequently, to identify potential effects of urban runoff on aquatic life and on water supplies, a comparison of both total recoverable and total metal concentrations against respective criteria and standards is needed.

As part of this project, 17 non-priority pollutant metals were also measured in the three fractions since the analytical procedures provide this information at no additional cost. These data are available to all NURP cities and may be analyzed for potential water quality impacts in future EPA NURP assessments. The concentrations of three of these metals (Ca, Mg, and Sr) were used to calculate hardness for each sample. These hardness values were then used to calculate the applicable EPA water quality criteria for selected priority pollutant metals with hardness-dependent criteria.

METHODOLOGY

Twenty-five NURP cities (Table 9 and Figure 2) are participating in this project. These cities have been supplied sampling kits with sufficient supplies to collect eight runoff samples for each of the three fractions. Consequently, a maximum of 200 samples can be analyzed for each of the three fractions. Along with the sampling kit, a sampling manual and recommendations on sampling were provided. These recommendations are as follows:

1. The samples collected should be either flow-composited or a series of discrete samples for a runoff event.
2. The special metals sample may be split out of the sample collected for priority pollutant analysis, or for those cities not participating in the toxic sampling program, the sample may be split out of a sample collected for conventional pollutant analysis.

The analytical methods followed by the contracted laboratory are in accordance with the EPA approved procedures published in Methods for Chemical Analysis of Water and Wastes (USEPA, 1979), and Inductively Coupled Plasma - Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes (USEPA, 1980). Table 10 summarizes the analysis procedures used and references the EPA methods and detection limits for each metal. The use of the Inductively Coupled Plasma-Atomic Emission Spectrometric Method (ICP) for trace element analysis of runoff samples provides a multi-element analysis at no additional cost.

Table 9

NURP Cities Participating in the Special Metals Sampling Project

Durham, NH*
Lake Quinsigamond, MA*
Mystic River, MA*
Irondequoit Bay, NY*
Lake George, NY*
Long Island, NY*
Baltimore, MD*
Washington, DC*
Knoxville, TN*
Tampa, FL*
Winston-Salem, NC
Champaign-Urbana, IL
Milwaukee, WI
Chicago, IL*
Tri-County, MI
Washtenaw, MI
Austin, TX*
Little Rock, AR*
Kansas City, MO*
Denver, CO*
Rapid City, SD*
Salt Lake City, UT*
Fresno, CA
Bellevue, WA*
Eugene, OR*

*Also participating in the NURP priority pollutant sampling program.

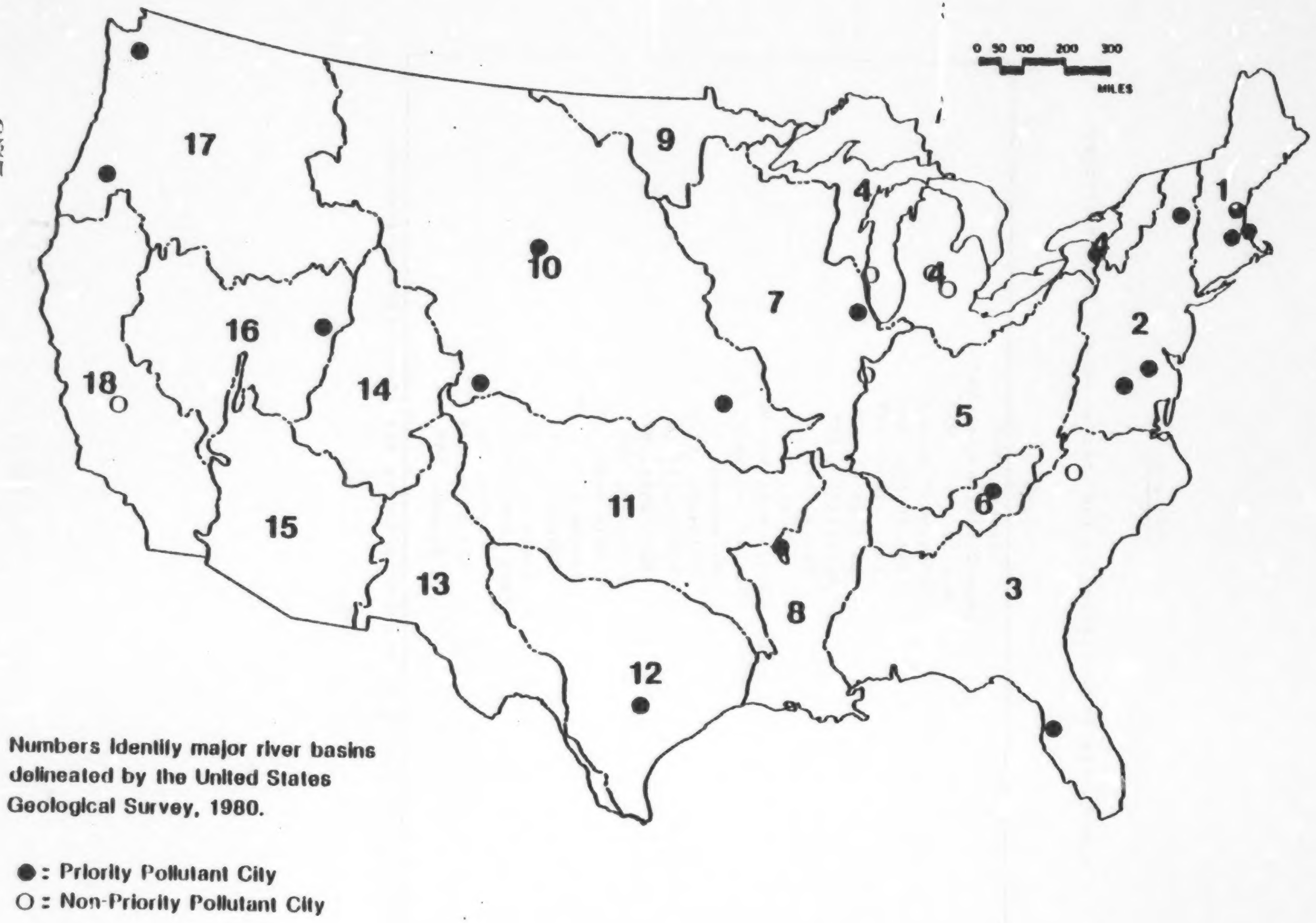

0 50 100 200 300
MILES
1
2
3
4
4
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Numbers identify major river basins delineated by the United States Geological Survey, 1980.
● : Priority Pollutant City
○ : Non-Priority Pollutant City

Figure 2 NURP Special Metals City Locations

Table 10

Summary of Analytical Procedures Used in the Special Metals Sampling Program

Metal	Method Analysis	Reference No.	Detection Limit ug/l
Arsenic (As)	Furnace AA (1)	206.2 (2)	10
Beryllium (Be)	ICP (3)	200.7 (4)	2
Cadmium (Cd)	ICP (3)	200.7 (4)	5
Chromium (Cr)	ICP (3)	200.7 (4)	10
Copper (Cu)	ICP (3)	200.7 (4)	20
Lead (Pb)	ICP (3)	200.7 (4)	40
Mercury (Hg)	Cold Vapor AA (5)	245.1 (2)	1
Nickel (Ni)	ICP (3)	200.7 (4)	20
Selenium (Se)	Furnace AA (2)	270.2 (2)	10
Silver (Ag)	ICP (3)	200.7 (4)	10
Thallium (Tl)	Furnace AA (2)	279.2 (2)	10
Zinc (Zn)	ICP (3)	200.7 (4)	10
Aluminum (Al)	ICP (3)	200.7 (4)	50
Barium (Ba)	ICP (3)	200.7 (4)	10
Boron (B)	ICP (3)	200.7 (4)	10
Calcium (Ca)	ICP (3)	200.7 (4)	100
Cobalt (Co)	ICP (3)	200.7 (4)	10
Iron (Fe)	ICP (3)	200.7 (4)	20
Lithium (Li)	ICP (3)	200.7 (4)	10
Magnesium (Mg)	ICP (3)	200.7 (4)	100
Manganese (Mn)	ICP (3)	200.7 (4)	10
Molybdenum (Mo)	ICP (3)	200.7 (4)	10
Potassium (K)	ICP (3)	200.7 (4)	200
Sodium (Na)	ICP (3)	200.7 (4)	100
Strontium (Sr)	ICP (3)	200.7 (4)	10
Tin (Sn)	ICP (3)	200.7 (4)	50
Titanium (Ti)	ICP (3)	200.7 (4)	10
Vanadium (V)	ICP (3)	200.7 (4)	10
Yttrium (Y)	ICP (3)	200.7 (4)	10

Footnotes:

[1] Atomic Absorption, Furnace Technique.

[2] U.S. Environmental Protection Agency. 1979. Methods for the Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory. Office of Research and Development. Cincinnati, Ohio.

[3] Inductively Coupled Plasma-Atomic Emission Spectrometric Method.

[4] U.S. Environmental Protection Agency. 1980. Inductively Coupled Plasma-Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory. Office of Research and Development. Cincinnati, Ohio.

[5] Manual Cold Vapor Atomic Absorption Technique.

Therefore, besides data on the priority pollutant metals, which are of primary concern, data on 17 additional metal elements are provided.

Four data analysis approaches are used to summarize preliminary results:

1. Metals are identified by frequency of detection, including calculations of geometric mean concentrations of each fraction (total, total recoverable, and dissolved).

2. Comparisons are made of priority pollutant metals concentrations (total recoverable and total metal) of undiluted urban runoff with EPA's water quality criteria and drinking water standards, respectively. These comparisons identify exceeded criteria and standards in an effort to evaluate the potential downstream effects on aquatic life as well as the potential impacts on water supplies.

   EPA water quality criteria for the protection of aquatic life are of two types: (1) "acute" represent the maximum concentration of a pollutant at any time; (2) "chronic" represents the maximum 24-hour average concentration allowed.

   Those criteria that are hardness dependent were adjusted using the hardness values calculated for each water sample using Ca, Mg and Sr concentrations. (Hardness values ranged from 11.2 to 452 with the arithmetic mean being 113 mg/l.)

3. Comparisons are made of dissolved metals concentrations with total and total recoverable concentrations to identify the relative importance of each fraction for each metal.

4. Comparisons are made of special metal concentrations with results of metals analyzed in the NURP priority pollutant monitoring effort when samples were sampled simultaneously for both programs.

5. Comparisons are made of non-priority pollutant metal concentrations (total metal) found in undiluted urban runoff with EPA's "Red Book" Criteria.

At this time, the focus of the data analysis is on the priority pollutant metals. A range of the geometric mean was calculated for each parameter, based on assumptions made in the EPA-Water Planning Division report "Preliminary Results of the NURP Program." Since it is not appropriate to calculate a mean if most of the values are undetected, only metals found in at least 10 percent of the samples are included in this analysis. Two geometric means were computed to identify a range within which the actual mean falls. The upper end of the range was calculated using the actual detection limit when the pollutant was undetected. The lower end was calculated using a very small number (0.1 times the detection limit) for the undetectable (remarked) result in order to avoid zero, which cannot be accommodated in geometric mean calculations. Mean concentrations were also only calculated on composite samples; therefore, the total sample size was 46. The 14 discrete samples were excluded because they do not provide an adequate representation of the runoff event concentration.

The data analysis used event mean concentration which is calculated by dividing the mass discharge, whether it be total, total recoverable, or dissolved, by the total runoff volume. If a flow-weighted composite was collected, the metal concentration was used to represent the event mean concentration. No flow data were reported for discrete samples and, consequently, event mean concentrations could not be calculated. These discrete samples did provide data on the instantaneous metal content of various periods in a runoff event and were used in determining the percent of total metal in the various metal fractions.

278

FINDINGS

Raw sampling data for all pollutants are given in Appendix E and summarized in Table 11. Appendix F contains preliminary laboratory quality control (QC) data. In general this QC data meets established laboratory control limits (except for aluminum, boron, and iron), including control limits specified in "Quality Assurance for Laboratory Analysis of 129 Priority Pollutants" (U.S. Environmental Protection Agency, Monitoring and Data Support Division, February 4, 1980). Recoveries for spiked samples, method standards, and reference standards are within 90 to 110 percent for most metals, and replicate standard deviations (RSD's) for duplicate samples are generally less than 10 percent.

Specific results and findings are summarized below:

1. Eight priority pollutant metals were detected in the total fraction. Their frequency of detection and range of values are shown below. The range surrounding the geometric mean is also provided for the metals found in at least 10% of the samples.

	Frequency Found Above Detection Limit (%)	Range of Detected Values (ug/l)	Range of Geometric Mean* (ug/l)
Zinc	92	10-730	103-133
Lead	70	40-740	43-106
Copper	53	20-120	7-27
Chromium	45	10-80	4-14
Nickel	27	20-60	4-21
Cadmium	8	5	-
Beryllium	8	2	-
Arsenic	3	10-20	-

*Based on "total metal" values calculated in Appendix E and presented in Table 11.

Table 11
Summary of Number of Detections, Mean Concentrations, Range and Detection Limits for
Special Metals Data Collected as of October 1981
(Composite Samples Only - 46 Samples: concentrations in ug/l)

Pollutant	Form	Number of Detected Values	Geometric Mean RMK = 0.10 RMK*	Geometric Mean RMK = RMK*	Range of Detected Values	Detection Limit
Arsenic	Total	1	-	-	20	10
	Total Recoverable	0	-	-	-	10
	Dissolved	0	-	-	-	10
Beryllium	Total	4	-	-	2	2
	Total Recoverable	0	-	-	-	2
	Dissolved	1	-	-	2	2
Cadmium	Total	4	-	-	5	5
	Total Recoverable	1	-	-	5	5
	Dissolved	2	-	-	5 - 10	5
Chromium	Total	20	4	14	10 - 80	10
	Total Recoverable	13	2	12	10 - 80	10
	Dissolved	0	-	-	-	10
Copper	Total	20	7	27	20 - 120	20
	Total Recoverable	21	8	27	20 - 110	20
	Dissolved	4	-	-	20 - 80	20
Lead	Total	28	43	106	40 - 740	40
	Total Recoverable	28	42	103	40 - 740	40
	Dissolved	0	-	-	-	40
Mercury	Total	0	-	-	-	1
	Total Recoverable	0	-	-	-	1
	Dissolved	1	-	-	1	1
Nickel**	Total	12	4	21	20 - 60	20
	Total Recoverable	4	-	-	20 - 40	20
	Dissolved	1	-	-	140	20
Selenium	Total	0	-	-	-	10
	Total Recoverable	0	-	-	-	10
	Dissolved	0	-	-	-	10
Silver	Total	0	-	-	-	10
	Total Recoverable	0	-	-	-	10
	Dissolved	0	-	-	-	10

*RMK = REMARK and indicates non-detection.

**Contamination suspected in dissolved fraction.

Table 11 (Cont.)

Summary of Number of Detections, Mean Concentrations, Range and Detection Limits for
Special Metals Data Collected as of October 1981
(Composite Samples Only - 46 Samples: concentrations in ug/l)

Pollutant	Form	Number of Detected Values	Geometric Mean RMK = 0.10 RMK*	Geometric Mean RMK = RMK*	Range of Detected Values	Detection Limit
Thallium	Total	0	-	-	-	10
	Total Recoverable	0	-	-	-	10
	Dissolved	0	-	-	-	10
Zinc	Total	41	103	133	10 - 730	10
	Total Recoverable	43	118	137	20 - 690	10
	Dissolved	37	28	43	10 - 550	10
Aluminum	Total	45	2,305	2,423	200 - 74,400	50
	Total Recoverable	46	1,487	1,487	50 - 44,900	50
	Dissolved	12	11	58	50 - 500	50
Barium	Total	43	43	50	10 - 600	10
	Total Recoverable	42	34	41	10 - 570	10
	Dissolved	38	28	42	10 - 190	10
Boron**	Total	32	13	27	10 - 180	10
	Total Recoverable	43	27	32	10 - 160	10
	Dissolved	38	22	33	10 - 230	10
Calcium	Total	46	20,220	20,220	3,100 - 121,000	100
	Total Recoverable	46	19,289	19,289	3,000 - 121,000	100
	Dissolved	46	13,925	13,925	2,500 - 153,000	100
Cobalt	Total	2	-	-	20 - 30	10
	Total Recoverable	4	-	-	10 - 20	10
	Dissolved	0	-	-	-	10
Iron	Total	46	3,531	3,531	300 - 69,900	20
	Total Recoverable	46	2,668	2,668	280 - 48,600	20
	Dissolved	37	31	49	20 - 470	20
Lithium	Total	11	2	14	10 - 1,140	10
	Total Recoverable	10	2	13	10 - 1,200	10
	Dissolved	9	2	12	10 - 1,300	10
Magnesium	Total	46	5,339	5,339	900 - 26,800	100
	Total Recoverable	46	5,200	5,200	900 - 25,100	100
	Dissolved	46	2,745	2,745	300 - 28,500	100

*RMK = REMARK and indicates non-detection.

**Contamination suspected in dissolved fraction.

281

Table 11 (Cont.)

Summary of Number of Detections, Mean Concentrations, Range and Detection Limits for
Special Metals Data Collected as of October 1981
(Composite Samples Only - 46 Samples: concentrations in ug/l)

Pollutant	Form	Number of Detected Values	Geometric Mean RMK = 0.10 RMK*	Geometric Mean RMK = RMK*	Range of Detected Values	Detection Limit
Manganese	Total	45	124	130	10 - 1,620	10
	Total Recoverable	45	124	130	10 - 1,550	10
	Dissolved	30	11	25	10 - 290	10
Molybdenum	Total	4	-	-	10 - 20	10
	Total Recoverable	0	-	-	-	10
	Dissolved	1	-	-	10	10
Potassium	Total	46	2,941	2,941	700 - 16,900	200
	Total Recoverable	46	2,825	2,825	400 - 14,600	200
	Dissolved	46	3,130	3,130	800 - 6,300	200
Sodium	Total	46	5,992	5,992	700 - 142,000	100
	Total Recoverable	46	6,158	6,158	900 - 148,000	100
	Dissolved	46	6,913	6,913	900 - 160,000	100
Strontium	Total	46	86	86	20 - 4,490	10
	Total Recoverable	46	86	86	20 - 4,290	10
	Dissolved	46	66	66	10 - 5,200	10
Tin	Total	3	-	-	50	50
	Total Recoverable	0	-	-	-	50
	Dissolved	0	-	-	-	50
Titanium	Total	36	38	59	20 - 2,490	10
	Total Recoverable	40	39	53	10 - 890	10
	Dissolved	1	-	-	20	10
Vanadium	Total	14	3	13	10 - 160	10
	Total Recoverable	13	2	12	10 - 90	10
	Dissolved	0	-	-	-	10
Yttrium	Total	3	-	-	20 - 40	10
	Total Recoverable	5	1	11	10 - 40	10
	Dissolved	0	-	-	-	10

*RMK = REMARK and indicates non-detection.

2. Comparisons of total recoverable and total metal concentrations (undiluted by stream flow) with EPA water quality criteria and drinking water standards, respectively, reveal that lead, copper, and zinc exceed acute criteria in greater than 37 percent of the samples while they exceed chronic criteria in greater than 53 percent of the samples (Table 12). Lead concentrations were found to exceed EPA's drinking water standards in 63 percent of the samples.

3. A comparison of the priority pollutant metal fractions (Table 13a) revealed that, in general, most of the metals are in the particulate form; most of the metals associated with particulates are in the total recoverable fraction. However, copper, and zinc both are present at 27 percent in the dissolved form. For non- priority metals (Table 13b), a larger percent of the metal concentration is in the dissolved fraction. More than 90 percent of potassium, sodium, lithium, and boron are present in the dissolved fraction, as expected due to the high solubility of these metal salts.

4. Four of the non-priority metals (barium, boron, iron and manganese) have criteria available in EPA's "Red Book" (Table 14). In undiluted runoff, barium and boron did not exceed criteria; iron and manganese exceeded the criteria for domestic water supplies (welfare) in 98% and 77% of the respective samples. These criteria are established to prevent brownish staining of laundry and plumbing fixtures and objectional taste in beverages.

CONCLUSIONS

For this preliminary screening analysis, the results indicate that zinc, lead, copper and chromium are the metals found most frequently and at the highest concentration.

Lead concentrations in undiluted runoff were found to exceed the drinking water standard and human health criterion of 50 ug/l (total lead) in 63 percent of the samples, with detected total lead concentrations ranging

Table 12

Summary of Water Quality Criteria Violations
(Analyses of data uses detected values only)

Metal	# of Samples	Percentage of Samples in Violation			
		Freshwater Acute	Freshwater Chronic	Human Health	Drinking Water Standard
Arsenic	60	0	0	0[c]	0
Beryllium	60	0	0	0[c]	NS
Cadmium	60	3[c]	3[c]	2	2
Chromium	60	0	2	2	2
Copper	60	42[b,c]	53[b,c]	NCA	0
Lead	60	43[b]	68[b,c]	63[b]	63[b]
Mercury	60	0	0	0[c]	0
Nickel	60	0	0	12[c]	NS
Selenium	60	0	0	0	0
Silver	60	0[c]	0[c]	0	0
Thallium	60	0	0	0	0
Zinc	60	37[b]	85[b]	NCA	0

Footnotes:

[a] Violations based on total recoverable fraction only.

[b] Five violations as a result of 5 discrete samples collected for a single runoff event in Long Island, NY., May 11, 1981.

[c] Detection limit is higher than criteria for the metal; therefore, the violation incidence could be higher than shown.

Table 13a

Total Recoverable and Dissolved Metals Concentration as a Percent of Total Metals Concentration:[1] Priority Pollutant Metals

(Based on 60 samples)

		Percent Total Recoverable	Percent Dissolved	Frequency of Detection in Total Fraction (%)
Arsenic[2]	RMK[3] = 0	-	-	2
	RMK = RMK	-	-	
Beryllium[2]	RMK = 0	-	-	7
	RMK = RMK	-	-	
Cadmium[2]	RMK = 0	-	-	7
	RMK = RMK	-	-	
Chromium	RMK = 0	61	0	33
	RMK = RMK	77	41	
Copper	RMK = 0	93	27	33
	RMK = RMK	94	53	
Lead	RMK = 0	94	4	47
	RMK = RMK	95	18	
Mercury[2]	RMK = 0	-	-	0
	RMK = RMK	-	-	
Nickel[4]	RMK = 0	35	-	20
	RMK = RMK	85	-	
Selenium[2]	RMK = 0	-	-	0
	RMK = RMK	-	-	
Silver[2]	RMK = 0	-	-	0
	RMK = RMK	-	-	
Thallium[2]	RMK = 0	-	-	0
	RMK = RMK	-	-	
Zinc	RMK = 0	64	27	68
	RMK = RMK	65	28	

[1] Determined using only those samples with a detectable level of metal in the total fraction for greater than 10% of the samples analyzed.

[2] Fewer than 10% of the samples had detectable levels of metal in the total fraction.

[3] RMK = 0: Percentages have been calculated substituting zero for less than detectable values in the dissolved and total recoverable fractions.

RMK = RMK: Percentages have been calculated substituting the detectable limit for less than detectable values in the dissolved and total recoverable fractions.

[4] One data point eliminated from data set due to field contamination.

Table 13b

Total Recoverable and Dissolved Metals Concentration as a Percent of Total Metals Concentration:[1]
Non-Priority Pollutant Metals
(Based on 60 samples)

		Percent Total Recoverable	Percent Dissolved	Frequency of Detection In Total Fraction (%)
Aluminum	RMK[3] = 0	64	1	75
	RMK = RMK	64	1	
Barium	RMK = 0	85	87	72
	RMK = RMK	86	89	
Boron[4]	RMK = 0	100+	100+	53
	RMK = RMK	100+	100+	
Calcium	RMK = 0	95	61	77
	RMK = RMK	95	61	
Cobalt[2]	RMK = 0	-	-	3
	RMK = RMK	-	-	
Iron	RMK = 0	75	1	77
	RMK = RMK	75	1	
Lithium	RMK = 0	97	100	18
	RMK = RMK	99	100+	
Magnesium	RMK = 0	97	66	77
	RMK = RMK	97	66	
Manganese	RMK = 0	97	18	75
	RMK = RMK	97	19	
Molybdenum[2]	RMK = 0	-	-	7
	RMK = RMK	-	-	
Potassium	RMK = 0	90	92	77
	RMK = RMK	90	92	
Sodium	RMK = 0	99	100+	77
	RMK = RMK	99	100+	

Table 13b (Cont.)
Total Recoverable and Dissolved Metals Concentration as a Percent of Total Metals Concentration:[1]
Non-Priority Pollutant Metals
(Based on 60 samples)

		Percent Total Recoverable	Percent Dissolved	Frequency of Detection in Total Fraction (%)
Strontium	RMK = 0	96	93	77
	RMK = RMK	96	93	
Tin[2]	RMK = 0	-	-	5
	RMK = RMK	-	-	
Titanium	RMK = 0	59	0	60
	RMK = RMK	59	5	
Vanadium	RMK = 0	63	0	23
	RMK = RMK	71	32	
Yttrium[2]	RMK = 0	-	-	5
	RMK = RMK	-	-	

---

[1] Determined using only those samples with a detectable level of metal in the total fraction for greater than 10% of the samples analyzed.

[2] Fewer than 10% of the samples had detectable levels of metal in the total fraction.

[3] RMK = 0: Percentages have been calculated substituting zero for less than detectable values in the dissolved and total recoverable fractions.
RMK = RMK: Percentages have been calculated substituting the detectable limit for less than detectable values in the dissolved and total recoverable fractions.

[4] Contamination suspected in the dissolved fraction.

Table 14

Summary of Violations of EPA's "Red Book" Criteria for Non-Priority Pollutant Metals (1) (in undiluted Urban Runoff)

Metal	Criteria (ug/l)	Number of Samples	Range of Detected Values (ug/l)	% of Samples in Violation	Detection Limit (ug/l)
Barium	1000 (2)	60	10-320	0	10
Boron	750 (3)	60	10-180	0	10
Iron	300 (4)	60	300-69900	98	20
Manganese	50 (4)	60	10-1620	77	10

[1] Violations based on total metal fraction only.

[2] Domestic water supply (health)

[3] Long term irrigation on sensitive crops

[4] Domestic water supplies (welfare)

from 40-740 ug/l. Although dilution by receiving streams and subsequent treatment of river water by drinking water facilities would likely reduce these levels (particularly since it is in the suspended form), drinking water standard violations are still possible under worst case conditions. Such conditions would include cases where: (1) the runoff during a storm event was a large portion of the receiving water flow, resulting in a dilution of less than 1 to 15; (2) the preliminary sampling results were representative of lead concentrations above drinking water supply intakes; and (3) lead removal by public drinking water treatment facilities was minimal. Specific risks to drinking water supplies could be evaluated by confirmatory sampling during storm events.

In undiluted urban runoff, nickel concentrations exceed the human health criterion of 13.4 ug/l (total nickel) in 12 percent of the samples, with total detected nickel concentrations ranging from 20-60 ug/l. Violations are expected to be less than the 12 percent figure after dilution by receiving streams. Moreover, nickel is notconsidered a significant human health problem in water because it is poorly adsorbed by the body when ingested. Inhalation of nickel, especially nickel carbonyl, poses the greatest risk to human health.

Lead, copper and zinc concentrations in undiluted runoff exceed freshwater acute criteria in greater than 37 percent of the samples, with the largest observed concentration being less than 10 times the respective criteria. Depending upon receiving stream dilution, these pollutants could cause harm to aquatic life.

Lead, copper and zinc concentrations in undiluted runoff also exceed freshwater chronic criteria in greater than 53 percent of the samples. These criteria are allowable levels for 24 hours. Consequently, duration of the storm event and receiving stream flow are both important factors needed to fully evaluate the significance of these violations. Since most storms last between 2 and 16 hours, problems due to chronic criteria violations appear to be unlikely. The violations of acute criteria, however, could be significant in longer term storms with low dilutions in receiving waters.

Only two priority pollutant metals (copper and zinc) were present in dissolved forms, to any great extent.

This screening approach does not account for the long-term water quality impacts that might occur as a result of the depositon of sediment and accumulation of toxic metals in stream bottoms. The sediments deposited as a result of urban runoff may be a source of toxic metal pollution due to deposition and resuspension.

In undiluted urban runoff, two non-priority pollutant metals (iron and manganese) exceed EPA's "Red Book" criteria established to prevent brownish staining of laundry and plumbing fixtures, and objectional taste in beverages. The high levels of these elements found in urban runoff is not unusual since the metals are ubiquitous in nature, and iron is the fourth most abundant element in the earth's crust.

REFERENCES

Athayde, D.N., et al. 1981. Preliminary Results of the Nationwide Urban Runoff Program, Volumes 1 and 2. Draft Report. U.S. Environmental Protection Agency, Water Planning Division, Washington, D.C.

Dalton·Dalton·Newport.

1981a. Priority Pollutants in Urban Stormwater Runoff: A Literature Review. Draft Report. EPA Contract No. 68-01-6195, Work Assignment No. 1, Dalton·Dalton·Newport, Cleveland, Ohio.

1981b. Methods for Analysis of Initial Nationwide Urban Runoff Program Data. Draft Report. EPA Contract No. 68-01-6195, Work Assignment No. 1, Dalton·Dalton·Newport, Cleveland, Ohio.

Shelly, P.E. 1979. Monitoring Requirements, Methods, and Costs for the Nationwide Urban Runoff Program. Reprinted from the Areawide Assessment Procedures Manual. EPA-600/9-76-014, U.S. Environmental Protection Agency, Water Planning Division. Washington, D.C.

Sunderman, F.W., Jr. 1981. Recent Research on Nickel Carcinogenesis. Environmental Health Perspectives, 40:131-141.

U.S. Environmental Protection Agency.

n.d. Data Collection Quality Assurance for the Nationwide Urban Runoff Program. EPA, Water Planning Division, Washington, D.C.

1980. Nationwide Urban Runoff Program, Data Management Procedures Manual. Draft. U.S. Environmental Protection Agency, Washington, D.C. 95 p.

1978. 1978-1983 Work Plan for the Nationwide Urban Runoff Program. U.S. Environmental Protection Agency, Water Planning Division, Washington, D.C. 75 p.

Versar.

1980a. Monitoring of Toxic Pollutants in Urban Runoff: A Guidance Manual. U.S. Environmental Protection Agency, Office of Water Regulations and Standards. Washington, D.C. 65 p.

1980b. Quality Assurance for Laboratory Analysis of 129 Priority Pollutants, Interim Report. U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C. 63 p.

APPENDIX G

PROJECT DESCRIPTIONS

APPENDIX G

FOREWORD

Descriptions for each of the twenty-eight NURP projects are presented in this appendix. The projects are presented in order by EPA Region number from I through X. There is at least one project in each region.

Descriptions are organized in a uniform format.

NATIONWIDE URBAN RUNOFF PROGRAM

NEW HAMPSHIRE WATER SUPPLY AND
POLLUTION CONTROL COMMISION

DURHAM, NH

REGION I, EPA

Introduction

The town of Durham, situated in Strafford County, is located in southeastern New Hamshire, approximately twelve miles inland from the Atlantic seacoast. Durham's topography consists of gently rolling hills and streams with these streams draining into the Oyster River and Oyster River estuary.

The Oyster River has been classified "Class A" west of Mill Road and "Class B" east of Mill Road. The water quality standards require that Class A waters be acceptable for public water supply after disinfection with no discharge of wastewater allowed, and that "Class B" waters be suitable for water supply after adequate treatment with no wastewater to be discharged unless adequately treated to maintain other classification parameters. Beneficial uses of the Oyster River include freshwater fishing, boating, and extensive shellfishing in the tidal flats.

The present water quality of the Oyster River and Oyster River estuary is good. However, it is important to note the high growth rate of coastal New Hamphire. Strafford and Rockingham counties, which encompass the entire coastal region of New Hampshire have increased in total population from 209,000 in 1970 to 259,000 in 1977. This represents an increase of 24 precent over seven years. Recent economic conditions have continued or even spurred the present development rate of the area.

Of concern to local and state agencies is the impacts that this rapid development will have upon the entire coastal area, including water quality resources.

Also, on a statewide level, under statute RSA 149:8 the staff is currently developing regulations for construction operations involving earth changing; including road building and repair, site development and hydrologic modifications. Under these proposed regulations a permit would require the use, as applicable, of best management practices to control erosion and sedimentation. Included in the recommendations for new developments is a requirement that the peak rate of runoff during and after site development should not exceed that occuring before the undertaking by more than about ten percent. The Durham study will aide developers, as well as regulatory agencies, in determining the best control alternatives and management practices.

PHYSICAL DESCRIPTION

A. Area

The town of Durham, situated in Strafford County, is located in Southeastern New Hampshire, approximately twelve miles inland from the Atlantic Seacoast. The total area of the Town comprises about 23.3 square miles of land and about 2.2 square miles of water. Land use within the town is characterized as institutional with associated residential and commercial development.

B. Population

In the northwesterly section of Durham, adjacent to the upper end of the Oyster River estuary, are situated the grounds and buildings of the University of New Hampshire. The most dense residential and commercial development has taken place in the area near the University. Present population including University enrollment is 15,100 and has been projected to increase to 22,500 in the year 2000.

C. Drainage

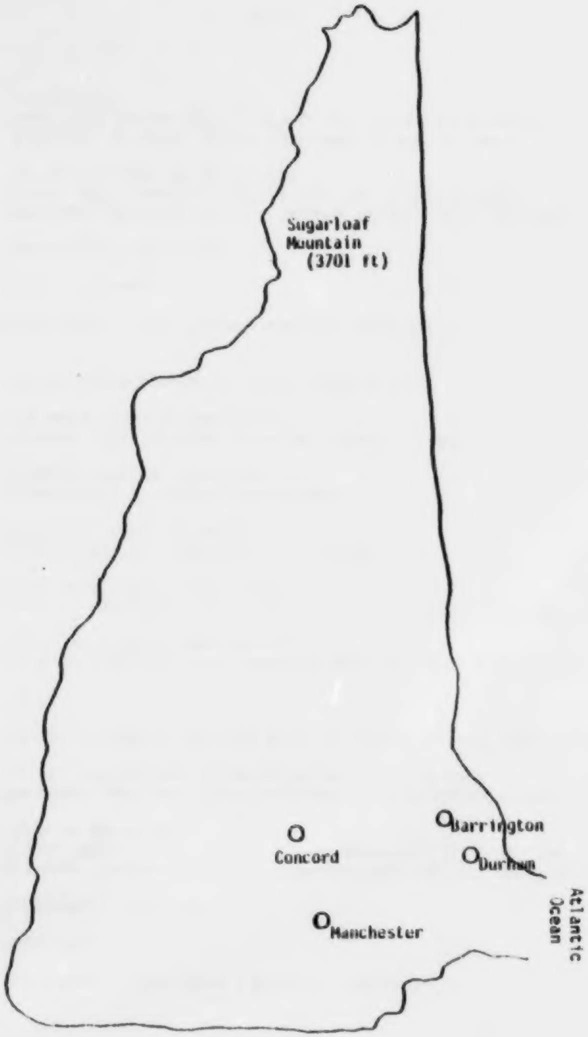
Durham's topography is typically New England with gently rolling hills and streams. These streams drain to the Oyster River and Oyster River Estuary.

The Oyster River originates in the southern portion of Barrington, New Hampshire. The river flows southeasterly through the Lee-Durham town borders and continues east through the north central portion of Durham. The river empties into the Great Bay at Durham Point, and is tidal up to the tide head dam in Durham at Route 108. It drains an area of 32 square miles. (see map)

D. Sewerage System

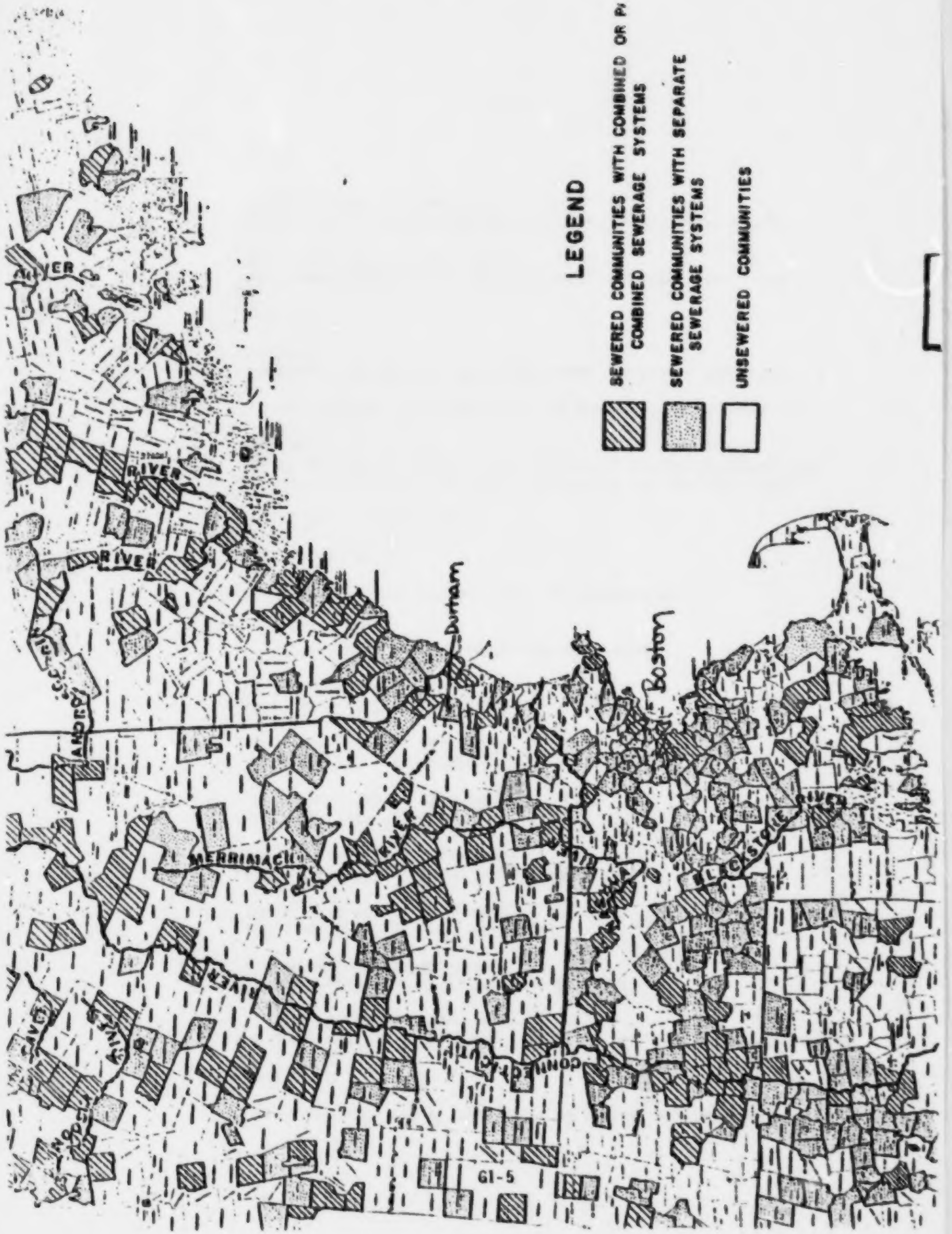
The existing sewage system serving the town of Durham and the University of New Hampshire is completely separated and consists of lateral sewers, intercepting sewers, the Dover Road pumping Station and force main, and a primary wastewater treatment plant. The sewage system contains a total of approximately 13.5 miles of gravity sewers serving a tributary area of about 800 acres and approximately 3,000 feet of 18 inch force main.

The primary wastewater treatment plant is currently being upgraded to secondary treatment. The construction phase is approximately 15% complete. The wastewater treatment plant discharges into the low reaches of the Oyster River estuary.



THE STATE OF NEW HAMPSHIRE

G1-4


LEGEND
SEWERED COMMUNITIES WITH COMBINED OR P/ COMBINED SEWERAGE SYSTEMS
SEWERED COMMUNITIES WITH SEPARATE SEWERAGE SYSTEMS
UNSEWERED COMMUNITIES
RIVER
RIVER
RIVER
MERRIMACK
RIVER
CONNECTICUT
RIVER
BLACKSTONE RIVER
Durham
Boston

G1-5

PROJECT AREA

I. Catchment Name - 2 Pte (Pettee Brook at Madbury Road)

A. Area - 106 acres

B. Population - 2600 persons

C. Drainage - Pettee Brook is a tributary draining into the Oyster River. Main channel is 2800 ft. at approximately 37 ft/mile slope in the channel.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers. All of area is served by swales and ditches.

Streets consist of 100 lane miles of asphalt in good condition.

E. Land Use

20 acres (19%) is .5 to 2 dwelling units per acre urban residential.
2.4 acres (12%) is impervious.

16 acres (15%) is >8 dwelling units per acre urban residential.
1.76 acres (11%) is impervious.

9 acres (8%) is Central Business District.
8.55 acres (95%) is impervious.

6 acres (6%) is Shopping Center Area.
6 acres (100%) is impervious.

55 acres (52%) is Urban Institution (Univ. of NH).
5.5 acres (10%) is impervious.

≈ 23% imperviousness in entire drainage area.

II. Catchment Name - 3 Pte (Pettee Brook at Alumni Cntr.)

A. Area - 615 acres

B. Population - 100 persons

C. Drainage - Pettee Brook is tributary draining into the Oyster River. Main channel is 15,800 ft. long at approximately 42 ft/mile slope in the channel.

D. Sewerage - Drainage area of catchment is 15% separate storm sewers and 85% no sewers. All of area is served by swales and ditches.

Street consist of 4.83 lane miles of asphalt and other materials.

E. Land Use

30 acres (5%) is .5 to 2 dwelling units per acre urban residential.
1.38 acres (5%) is impervious.

10 acres (2%) is Central Business District.
9.5 acres (95%) is impervious.

135 acres (22%) is Urban Parkland.
.54 acres (<1%) is impervious.

18.5 acres (3%) is Urban Institutional.
3.09 acres (17%) is impervious

90 acres (15%) is Agriculture.
.84 acres (<1%) is impervious.

320 acres (52%) is Forest.
.96 acres (<1%) is impervious

11.5 acres (2%) is Water, Lakes.
0% impervious.

≈ 3% imperviousness in entire drainage area

III. Catchment Name - 5 Oys (Oyster River at Tidehead Dam)

A. Area - 2181 acres

B. Population - 3600 persons

C. Drainage - Drainage into site consists of 20% separate storm sewers and 80% no sewers. All of area is served by swales and ditches.

Streets consist of 31 lane miles of asphalt in good condition.

D. Sewerage - See above. 80% of drainage is through subsurface systems.

E. Land Use

430 acres (20%) .5 to 2 dwelling units per acre urban residential.
25.8 acres (6%) is impervious.

5 acres (.2%) >8 dwelling units per acre urban residential.
.5 acres (10%) is impervious.

2 acres (.09%) Central Business District.
1.9 acres (95%) is impervious.

8 acres (.4%) Shopping Center.
8 acres (100%) is impervious.

380 acres (17%) is Urban Parkland.
15 acres (4%) is impervious.

865 acres (40%) is Forest.
0% impervious.

21 acres (1%) is Water, Lakes.
0% impervious.

200 acres (9%) is Urban Institutional.
20 acres (10%) is impervious.

270 acres (12%) is Agriculture.
<5% is impervious.

≈3% of entire drainage area is impervious.

IV. Catchment Name - 7 Oys (Oyster River at Reservoir)

A. Area - 10,560 acres

B. Population - 300 persons

C. Drainage - 100% of area has no sewers.

Streets consist of 78 lane-miles with 62 lane-miles being asphalt in good condition.

D. Sewerage - No sewers. Drainage is all through subsurface systems.

E. Land Use

75 acres (1%) is .5 to 2 dwelling units per acre urban residential.
3.75 acres (5%) is impervious.

2 acres (<1%) is Central Business District.
1.9 acres (95%) is impervious.

11 acres (.1%) is Urban Industrial.
8.25 acres (75%) is impervious.

110 acres (1%) is Urban Parkland.
2.2 acres (2%) is impervious.

5 acres (<1%) is Urban Institutional.
.5 acres (10%) is impervious.

26 acres (.2%) is Agriculture.
.52 acres (2%) is impervious.

10326 acres (98%) is Forest.
5 acres is impervious.

≈.2% of entire drainage area is impervious

V. Catchment Name - 1 Pkg (Shop and Save Parking Lot)

A. Area - .90 acres

B. Population - 0

C. Drainage - 1 Pkg is a parking lot site drained entirely by separate storm sewers.

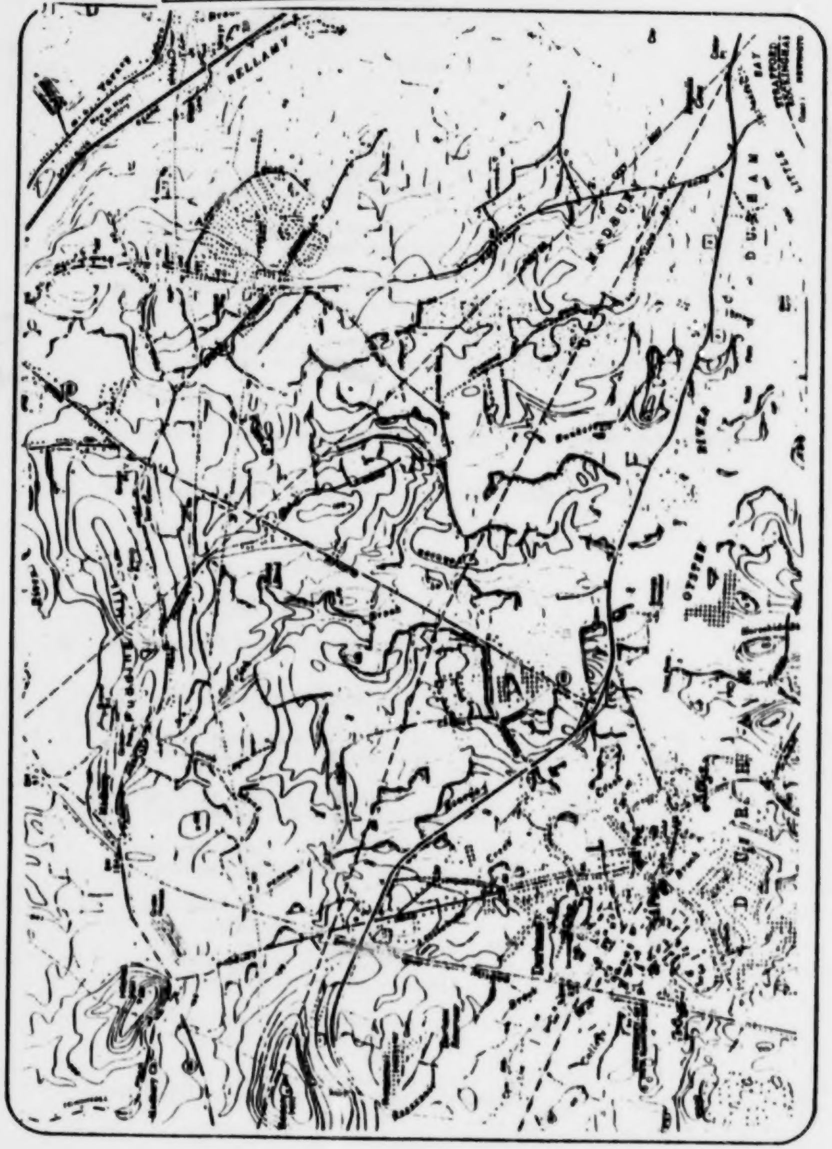
Drainage area of the parking lot is 100% asphalt streets.

D. See above

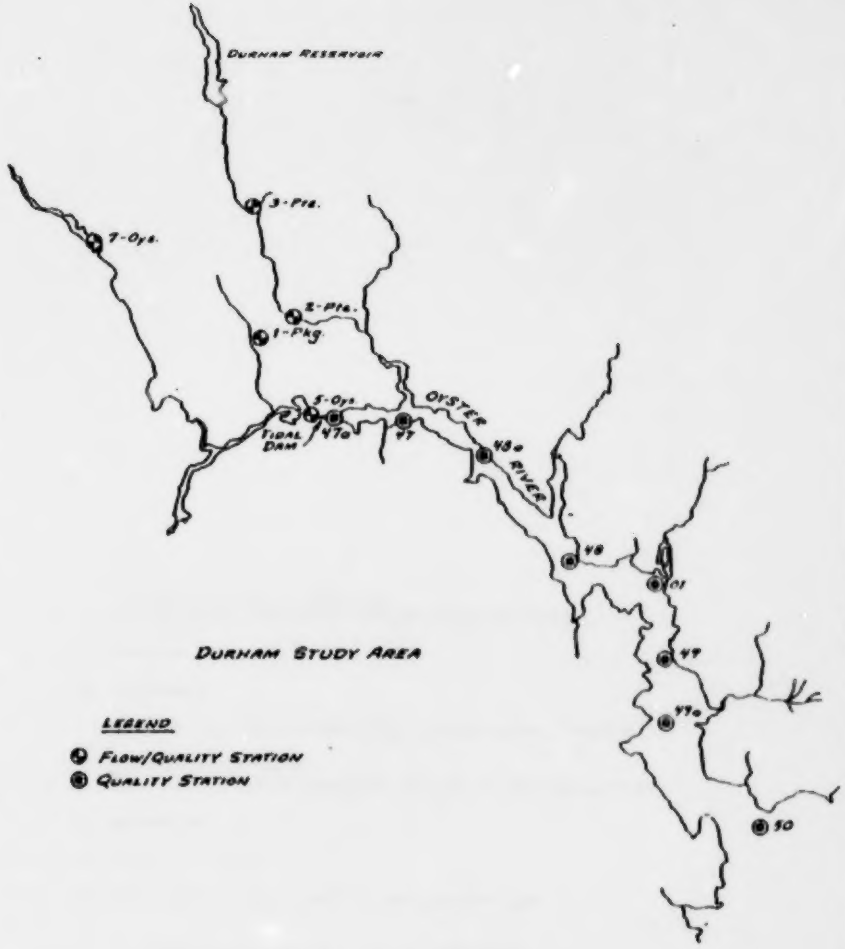
E. Land Use

40,000 ft^2 is Commercial Shopping Center of which
36,000 ft^2 (90%) is impervious

Reproduced from best available copy.



LOCATION OF SAMPLING SITES IN DURHAM, N.H.



Legend
- ⊕ Flow/Quality Station
- ◉ Quality Station

SCHEMATIC OF SAMPLING SITES

Project Description

A. Major objective

The final State of New Hampshire detailed 208 Water Quality Management Plan stated that the major emphasis of the 208 statewide effort is to control "existing and potential nonpoint source pollutions" as necessary to "meet the water quality goals of the state and the Fishable, Swimmable goal of the Act."

The Durham NURP study is a continuation of the earlier 208 effort and was structured to meet the objectives outlined in the final 208 plan. The project was broken into two phases; Phase I - Base Line Study and Phase II - Control Measures Study.

Phases I had several specific objectives. These were to 1) measure the mass loadings of urban runoff constituents during individual storm events, 2) measure the impact of urban runoff upon the receiving stream and relate this impact to possible violations of State Water Quality Standards and 3) model the impact of urban runoff upon the receiving estuary stream and relate this impact to possible violations of State Water Quality Standards.

One full year's data base, encompassing any seasonal variations which may exist, was obtained for Phase I.

Phase II of the study will begin with the cessation of the Phase I data base collection. The specific objectives of Phase II are to 1) measure the effectiveness of urban runoff degradation control measures in terms of cost versus mass loading reduction, 2) assess the impact of urban runoff degradation control measures upon the receiving stream and its State Water Quality Standards classification and 3) model the impact of urban runoff degradation control measures upon the receiving estuary and its State Water Quality Standards classification.

Phase II will also be one year in duration in order to encompass any seasonal influences upon the implemented control measures. In the study area the State felt that efforts to prevent or reduce storm water pollution would be best applied to developed areas in the Oyster River headwaters, since the Durham/Tidal Oyster River area is to a large extent developed. The study will concentrate on maintenance and operation practices that will attenuate or eliminate the degree of upset to the natural hydrologic balance of the watershed caused by urbanization in the lower Oyster River basin.

After the quantitative impact of the storm water pollution from the developed area has been estimated, the State feels that effective planning could be instituted by limiting the amount of stream degradation that could be tolerated during wet weather. The town of Durham could then determine what development options are available based on the residuals emitted from the remaining undeveloped Town area.

B. Methodologies

Presently there is little urban data base for the Town of Durham. Basically, this NURP study initiated the investigation of this phenomenon in the New Hampshire coastal area.

In the data collection effort, the quantity, as well as the quality, of urban runoff was examined. The hydrological causal factors of storm water runoff were recorded in order to ascertain their role and importance in the phenomenon of urban runoff. These factors include storm intensity, duration and frequency.

Land use within the study areas will also be characterized. These parameters are to be developed in relation to pollutant loadings results and compared with those of other studies in order to determine whether or not a correlating factor exists between land use and the amount of pollution associated with urban runoff.

Phase I consisted of gathering base line urban runoff data for the selected sub-catchments and the receiving stream. Phase II will consist of examining these sub-catchments after the implementation of control measures. In this way, the effectiveness of the control measures will be evaluated by calculating the difference in pollutant loads of the sub-catchments before and after the implementation of the selected control measures.

The cost-effectiveness of implementing control measures will be assessed in terms of total costs versus pollutant removal amount or percent. The relationship examined will be unique to the land use characteristics of the sub-catchments examined and to the hydrological stormwater conditions surrounding the storm events monitored.

Dry weather data was collected weekly for one year in the freshwater portion of the receiving stream. Receiving water stream data was also collected during storm events for comparisons with dry weather, as well as State Water Quality Standards. The purpose of these comparisons is, first, to determine how urban runoff and urban runoff control measures affect stream quality and, second, to evaluate these changes with respect to possible State Water Quality Standard Violations.

Estuary monitoring is also conducted on a periodic basis. The purpose of this monitoring is to collect data in order to calibrate and verify the estuary flushing model. The flushing model will be used to assess the effects of urban runoff and control measures upon estuary water quality.

C. Monitoring

The study area consists of a section of the Oyster River drainage basin encompassing the downtown area of Durham, NH. The monitoring program covers three in-town sub-catchments, the Oyster River and the Oyster River estuary.

One sub-catchment examined is a commercial parking lot in downtown Durham (1 Pkg). The second sub-catchment is larger and drains on institutional-commercial area of town (2 Pte). A third sub-catchment drains an area that is largely forest and agricultural land (3 Pte). This station is necessary to separate the upstream drainage from the downstream drainage. In addition, there are five stations to be monitored in the Oyster River and Oyster River estuary. The two upstream stations are located at impoundment sites in the River, the lower of which separates the freshwater and tidal portions of the River. The remaining three stations are located in the Estuary.

There is one rain gage operated on the University of New Hampshire campus. The gage is a Fisher-Porter model registering 0.1 inch increments of rainfall. An additional rain gage was installed at the parking lot site.

The list of parameters examined in each sample includes: Biochemical Oyygen Demand (BOD), Chemical Oyxgen Demand (COD), Nitrogen (NO_2 and NO_3), Total Phosphorus (P) and Chlorides (CL). Metals analyzed for include Cadmium, Lead, Chromium, Copper, Iron, Manganese, Nickel and Zinc. This dissolved and suspended nature of each of the parameters was tested. Temperature, pH, dissolved oxygen and aklalinity were also included.

Equipment

All monitoring sites, except those located in the estuary, have automatic sampling equipment. Following is a brief summary of the types of flow monitoring and automatic sampling equipment located at each site:

1 Pkg

ISCO model 1870 Flow meter and ISCO model 1680 sampler. Flow is measured by a flume located at the outflow of the catch basin.

2 Pte

ISCO model 1870 Flow meter and ISCO model 1680 sampler. Flow is measured using a weir located in the culvert.

3 Pte

ISCO model 1870 Flow meter and ISCO model 1680 sampler. Flow is measured using a weir located at the upstream end of the culvert.

5 Oys

ISCO model 1870 Flow meter and ISCO model 1680 sampler with model 1640 actuater. A rating curve was established at this site. The equipment is suspended in the fish ladder with a bubbler located at the dam.

7 Oys

ISCO model 1870 Flow meter and ISCO model 1680 sampler with model 1640 actuater. Equipment is located in gate house for the reservoir with bubbler located at the dam.

NATIONWIDE URBAN RUNOFF PROGRAM

MASSACHUSETTS DEPARTMENT OF
ENVIRONMENTAL QUALITY ENGINEERING

LAKE QUINSIGAMOND, MA

REGION I, EPA

INTRODUCTION

Lake Quinsigamond is located in the heart of Worcester County, Massachusetts and lies between the City of Worcester and the Town of Shrewsbury. The lake's drainage basin encompasses portions of Worcester, Shrewsbury, Boylton, and West Boylton, plus corners of Grafton and Millbury.

Lake Quinsigamond lies in a north-south direction and is crossed by three major highways: Interstate I-290, Route 9 and U.S. Route 20. Being situated in a highly urban area, the lake supports multiple recreational uses including fishing, boating, water skiing and bathing. The entire periphery of the lake is densely settled with many private homes and some commercial establishments.

The objectives of the Lake Quinsigamond NURP program are to assess the magnitude and severity of storm water runoff pollution in the lake and its tributaries; assess the cost, impacts and benefits of appropriate control techniques; recommend a comprehensive pollution abatement program for the watershed in order to protect, preserve, enhance and recover portions of the lake and its watershed for recreation, and propagation of fish and other aquatic life; and provide data on the character of urban runoff, its impacts on a major recreational lake as a receiving water, and on the effectiveness of various runoff control alternatives.

PHYSICAL DESCRIPTION

A. Area

Lake Quinsigamond is located in the heart of Worcester County, Massachusetts, between the city of Worcester and the town of Shrewsbury. Worcester and Shrewsbury are the two most populous municipalities in central Massachusetts. The lake's drainage basin also encompasses portions of the towns of Boylston, West Boylston, Grafton and Millbury. The entire periphery of the lake is densely settled with many private homes and some commercial establishments. Two state parks, several private beaches and marinas are located along the shorefront. The central part of the drainage basin is highly developed and considerable construction is occurring or is planned in the basin as a whole.

Being situated in a highly urban area with convenient access, the lake supports intensive, multiple recreational uses. These uses include fishing, swimming, boating, waterskiing, and aesthetic enjoyment. In addition, the lake recharges an aquifer providing water supply for Shrewsbury's lakeside wells.

Lake Quinsigamond is separated into two distinct sections: the deep narrow northern basin and the shallow southern basin known as Flint Pond.

The total area of the lake is 772 acres comprised of 475 acres in the northern basin and 297 acres in Flint Pond. The Lake Quinsigamond drainage basin occupies a total area of about 25 square miles (16,000 acres). The lake has a maximum depth of 92 feet and an average depth of 20.7 feet. The lake is approximately 5 miles long, with the width varying from 250 feet to nearly a mile. The lake volume is estimated at 688 million cubic feet.

The single outlet of the lake is located at Irish Dam with the outflow creating the Blackstone River. The major inlet to the lake is from a series of ponds north of the main body of the lake. Approximately 14 small tributaries also feed the lake. These tributaries drain sub-basins varying in size from less than one square mile to over 5 square miles.

B. Population

Worcester and Shrewsbury, which occupy the majority of the Lake Quinsigamond Basin, are the two most populous of the 27 municipalities in the Central Massachusetts Regional Planning Commission 208 Planning Area. In terms of generalized economic and demographic trends, Shrewsbury is characterized as an area of moderate to high population growth and industrial/commercial expansion. Boylston and West Boylston are characterized as areas of moderate to high population growth but slow industrial commercial expansion. Worcester, Grafton and Millbury are characterized as areas of slight decline or very slow population and industrial/commerical growth. Existing and projected populations or these areas are as follows:

	1975	1985
Worcester	171,859	169,400
Shrewsbury	21,858	24,200
Boylston	3,318	4,200
West Boylston	6,257	6,750
Grafton	10,584	11,000
Millbury	12,103	13,200

The entire periphery of the lake is densely settled with many private homes and some commercial establishments.

C. Drainage

The Lake Quinsigamond drainage basin is a headwater basin of the Blackstone River, rising immediately to the east of that river's origin. The Quinsigamond River is the lake's outlet and flows to its juncture with the Blackstone at Fisherville pond in the town of Grafton, MA.

The Blackstone River than carries the combined flows southeast into Rhode Island and the Seekonk River, which is tidal and flows into the Providence River and thence into Narragansett Bay.

Lake Quinsigamond lies in a region in which approximately half of the average annual precipitation eventually becomes streamflow, the remainder being lost to evapotranspiration. The most thorough study of the surface hydrology of Lake Quinsigamond and its tributary streams was carried out as part of the 1971 Water Quality study done by Massachusetts Division of Water Pollution Control. The discharge of the major tributaries was measured by current meter on three occasions. Of the fifteen feeder streams contributing flow to Lake Quinsigamond, six contributed over 90 percent of the surface flow: Tilly Brook, Newton Pond Overflow, Bonnie Brook, South Meadow Brook, Poor Farm Brook, and Coal Mine Brook.

A partial water balance was derived for the lake using data points which may be summarized as follows:

	4/26/71	6/30/71	12/17/71
Outflow (O)	38cfs	9cfs	47.2cfs
Evaporation (E)	3	6.4	1.5
Tributary Inflow (I)	30.37	9.94	39.63
O + E - I	10.63	5.46	9.07

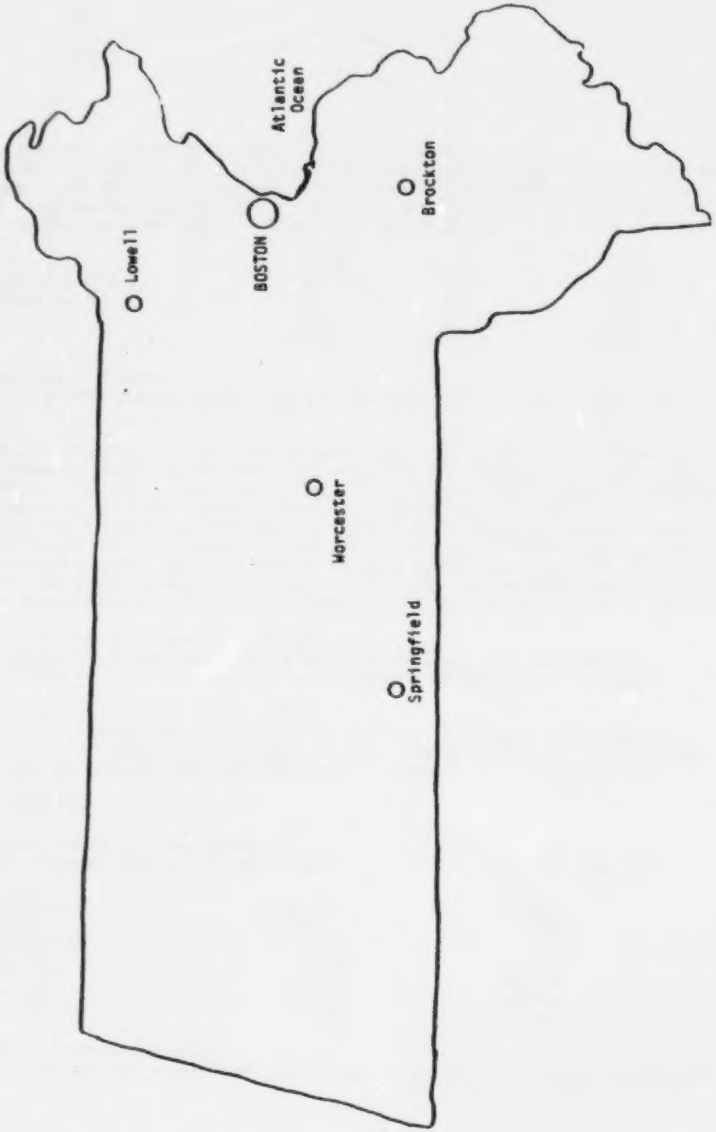
The outflow plus evaporation exceeds the inflow by the amount given in the last row. That amount approximately equals the release from storage plus roundwater inflow. Pumping from the Shrewsbury wells near the lake intercepts some of the groundwater inflow to the lake and may, if their zones of influence intersect the lake boundaries, cause a groundwater withdrawal from the lake.

The amount of stormwater runoff reaching Lake Quinsigamond is important since it is believed to have a significant pollutional impact. Using the measured outflow for the lake and the dry weather flow data gathered by MDWPC, an estimate of the total stormwater runoff was made. That estimate suggested that during the four month 1971 survey period, about 25 percent of the lake inflow was due to stormwater which entered the lake from the storm drains and feeder streams.

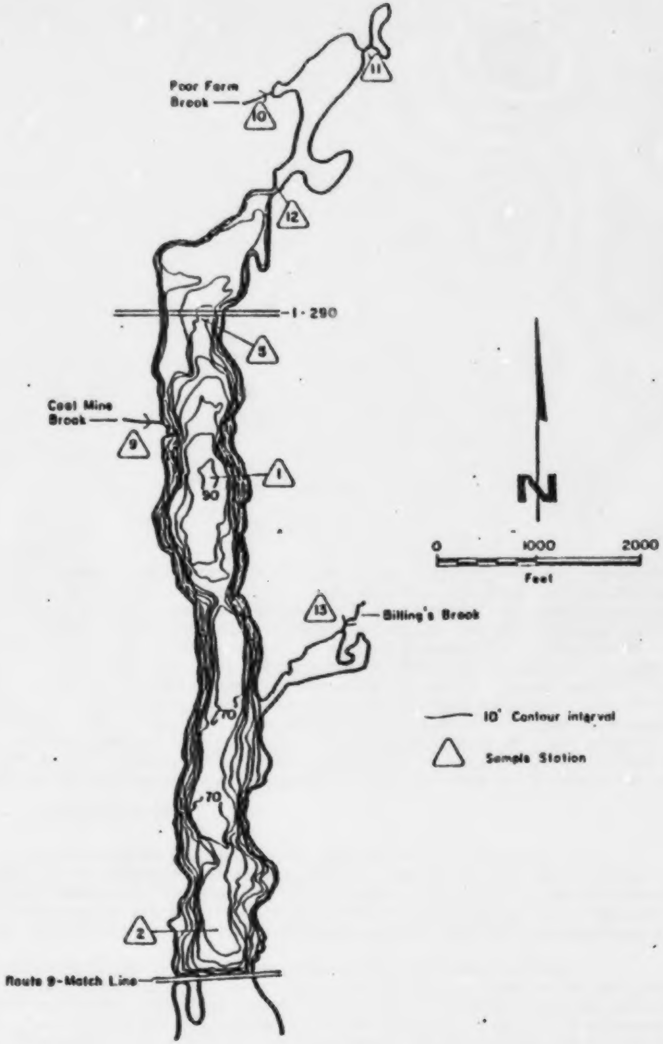
Lake Quinsigamond is stratified from May through November, during which time the water below the thermocline becomes trapped and remains in place until the lake becomes completely mixed during fall overturn. The surface inflow generally mixes with the epilimnion during stratification. The detention time of water in the epilimnion has been estimated to be between 125 and 150 days.

D. Sewerage System

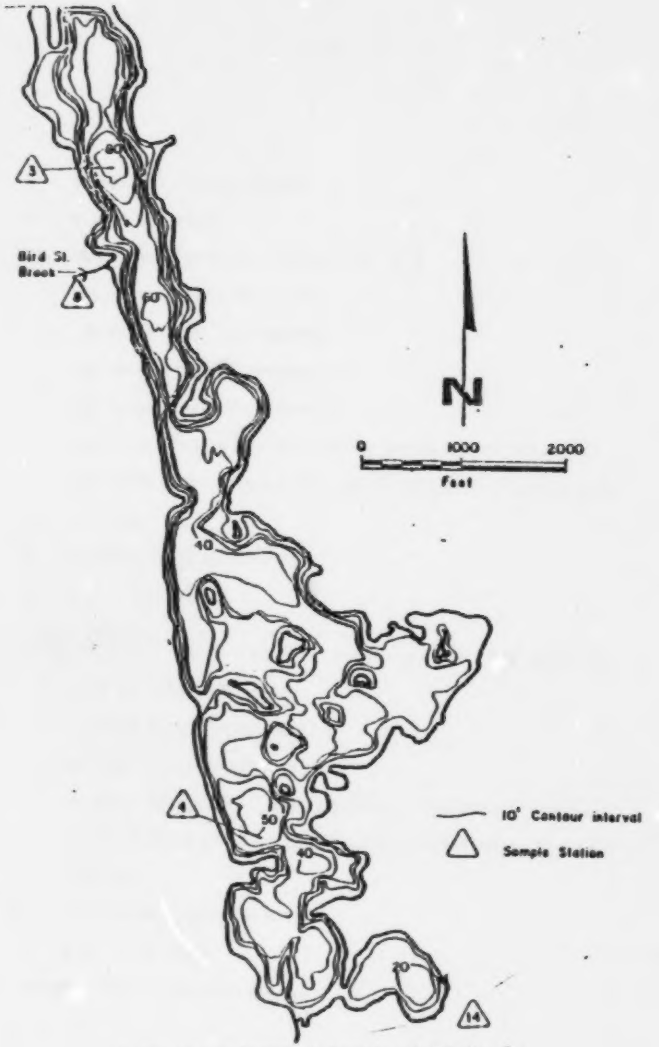
The Lake Quinsigamond watershed is mixture of separate storm sewers and septic tank systems. Within recent years elimination of point sources has been attempted by the construction of interceptor sewers and transmission lines which convey the wastewater out of the basin and southward to a regional treatment facility. However, there is evidence that sewage contamination is still occurring. The sources of the sewage contamination could be numerous. In areas without sanitary sewers, house connections have been identified as a source of sewage contamination. In general storm drains are constructed without a great deal of care to avoid infiltration and renegade sewage leaking from house connections has no difficulty reaching the storm drains. Additionally there may still be direct sewage connections draining to storm drains or major points of leakage between neighboring sanitary and storm lines. Common manholes were a problem in the past and may still be allowing some leakage.



THE STATE OF MASSACHUSETTS

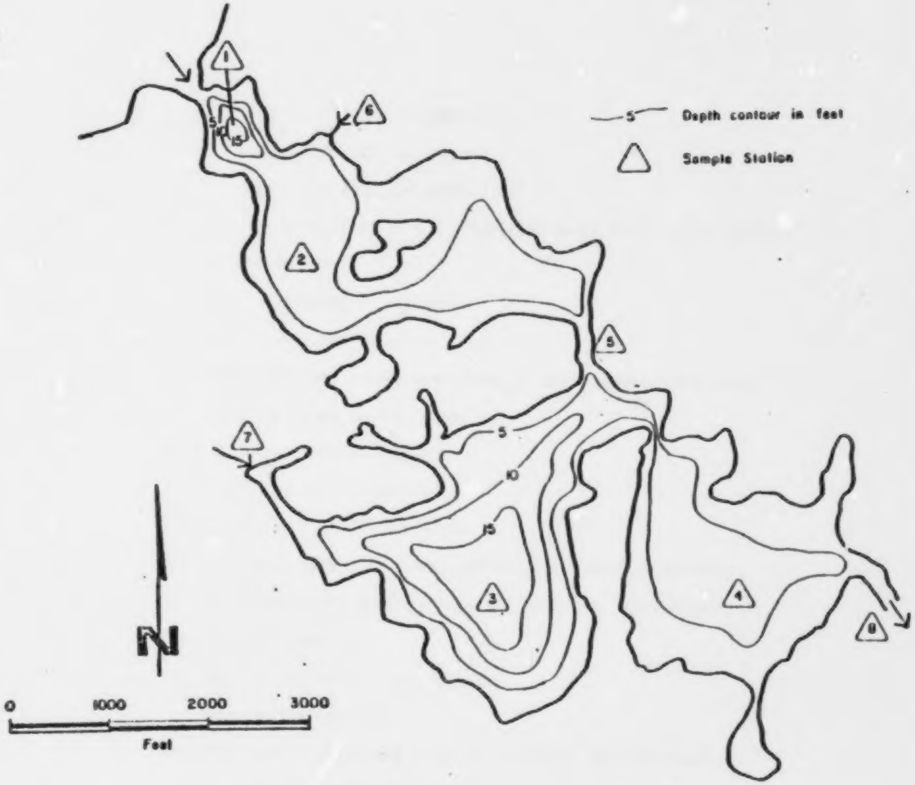


Lake Quinsigamond North of Route 9



Lake Quinsigamond South of Route 9

(cont.). Bathymetric Map of Lake Quinsigamond.



(c) Flint Pond

PROJECT AREA

I. Catchment Name - Jordan Pond (P1)

A. Area - 110 acres

B. Population - 1042 persons

C. Land Use

13 acres (12%) is 1/2 - 2 dwelling units per acre residential

74 acres (66%) is 2 - 8 dwelling units per acre residential

18 acres (16%) is commercial

4 acres (4%) is Industrial

2 acres (2%) is Parkland

II. Catchment Name - Route 9 Manhole, within Regatta Point fence at Police Station (P2)

A. Area - 338 acres

B. Population - 2285 persons

C. Land Use

138 acres (41%) is 2 -8 dwelling units per acre residential

21 acres (6%) is 9 + dwelling units per acre residential

82 acres (24%) is Commercial

36 acres (11%) is Industrial

40 acres (12%) is Parkland

22 acres (7%) is Open Land

III. Catchment Name - Manhole on Locust Ave (P3)

A. Area - 154 acres

B. Population - 1703 persons

C. Land Use

131 acres (85%) is 2 - 8 dwelling units per acre residential

2 acres (2%) is Commercial

12 acres (8%) is Industrial

7 acres (5%) is Parkland

IV. Catchment Name - Fitgerald Brook discharge to the Lake (P4)

A. Area - 601 acres

B. Population - 5491 persons

C. Land Use

363 acres (60%) is 2 - 8 dwelling units per acre residential

33 acres (5%) is 9 + dwelling units per acre residential

13 acres (3%) is Commercial

8 acres (2%) is Industrial

92 acres (15%) is Parkland

92 acres (15%) is Open Land

V. Catchment Name - Coal Mine Brook at Notre Dame Convent (P5)

A. Area - 100 acres

B. Population - 104 persons

C. Land Use

8 acres (8%) is 2 - 8 dwelling units per acre residential

63 acres (63%) is Commercial

9 acres (9%) is Parkland

20 acres (20%) is Open Land

VI. Catchment Name - Tilly Brook at Harvey Place Manhole (P6)

A. Area - 1690 acres

B. Population - 2845 persons

C. Land Use

171 acres (10%) is 1/2 - 2 dwelling units per acre residential

168 acres (10%) is 2 - 8 dwelling units per acre residential

112 acres (7%) is Commercial

27 acres (2%) is Industrial

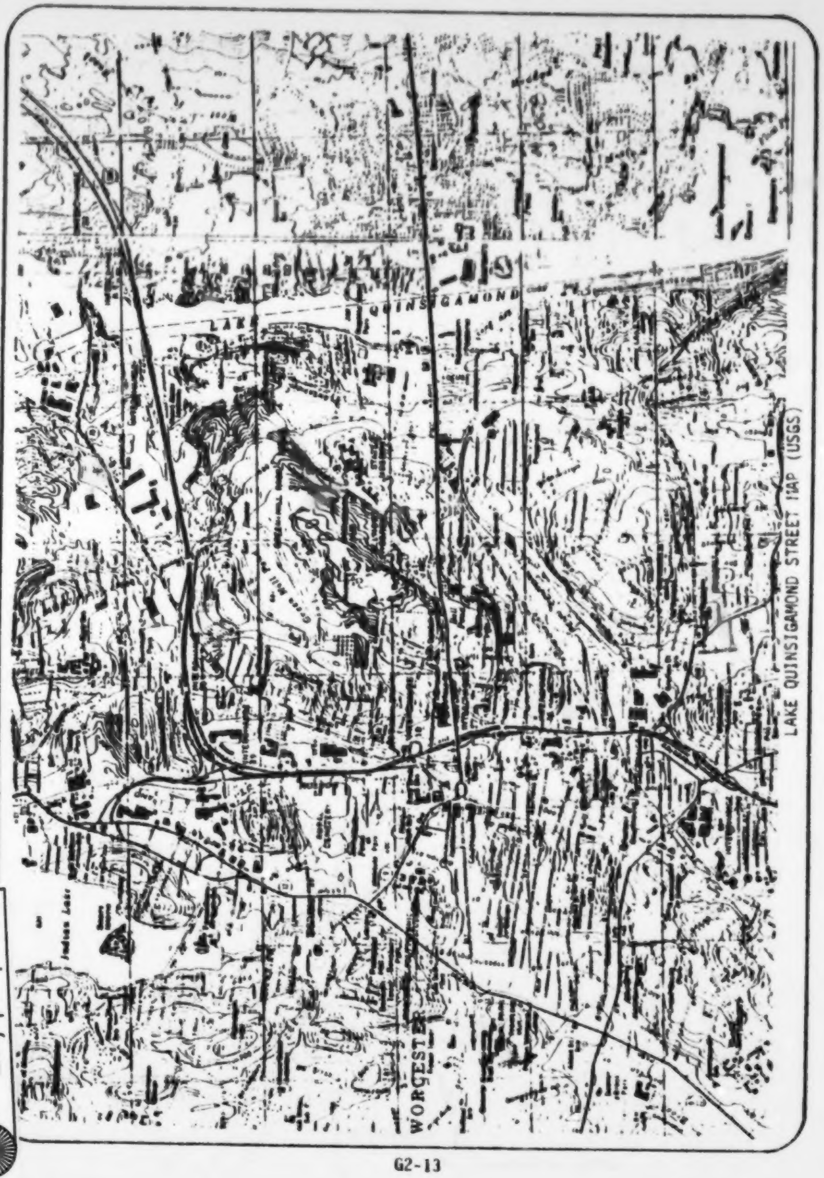
893 acres (53%) is Parkland

99 acres (6%) is Open Land

210 acres (12%) is Wetlands

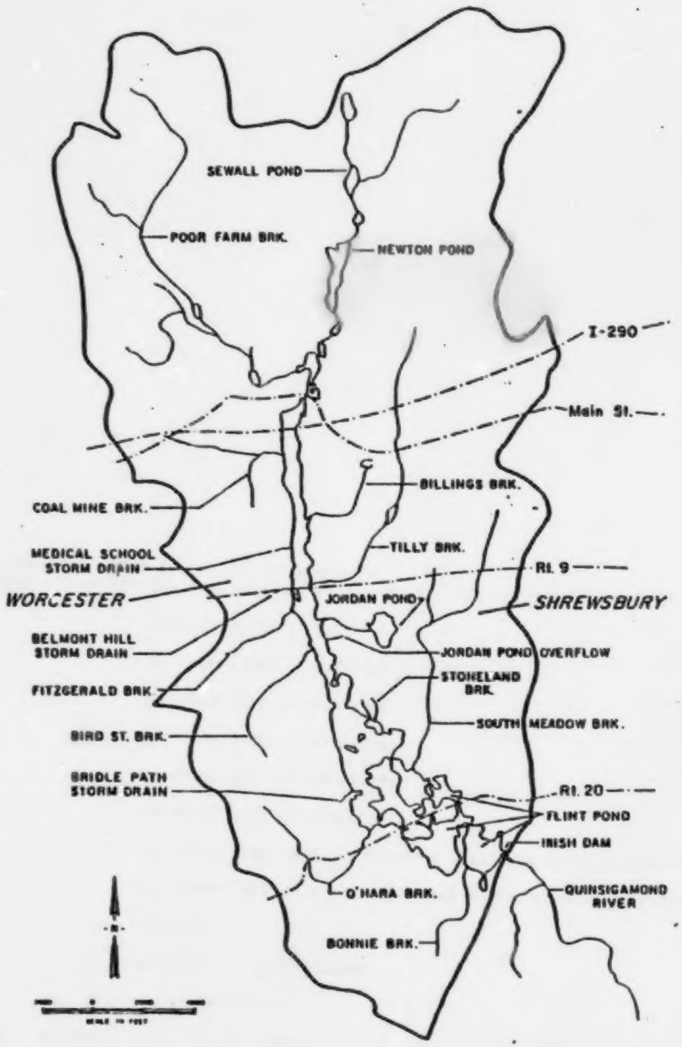
10 acres (>1%) is Lakes

Note: Drainage and Sewerage Information for the Individual sites was not provided in time for inclusion in Report.



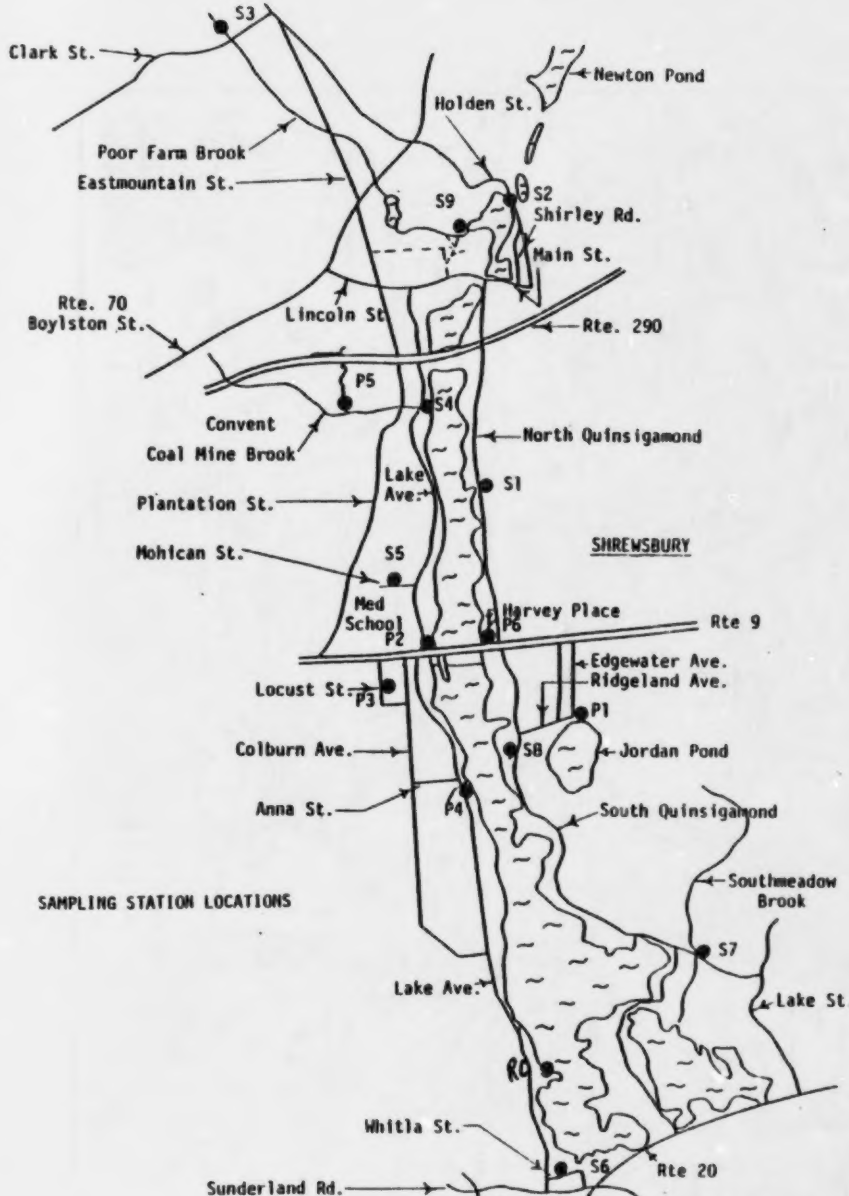
LAKE QUINSIGAMOND STREET MAP (USGS)

Reproduced from best available copy.



Lake Quinsigamond Drainage Basin

G2-14



SAMPLING STATION LOCATIONS

G2-15

LAKE QUINSIGAMOND

SAMPLING STATIONS

Lake Quinsigamond

STA #1 - Lake - 90'
STA #2 - Lake - 60'
STA #3 - Lake - 80'
STA #4 - Lake - 50'
STA #5 - Lake - Surface @ 290 Bridge
STA #6 - Lake - Surface @ Rte. 9 Bridge
STA #8 - Fitzgerald Brook
STA #9 - Coalmine Brook
STA #10 - Poor Farm Brook

STA #11- Newton Pond Outlet
STA #12- Lake @ Lincoln St.
STA #13- Billings Brook
STA #15- O'Hara Brook
STA #16- Medical School Drain
STA #17- Tilly Brook
STA #18- Jordan Pond Outlet
STA #19- Belmont Street Drain
STA #20- Channel below Belmont Street Drain

Flint Pond

STA #1 - Pond - 3m, 1.5m
STA #2 - Pond - @ surface
STA #3 - Pond - 4m, 2m
STA #4 - Pond - @ surface
STA #5 - Pond - @ surface

STA #6 - South Meadow Brook
STA #7 - Inlet from Lake Quinsigamond
STA #8 - Outlet of Pond @ Irish Dam
STA #9 - Bonnie Brook

LAKE QUINSIGAMOND NURP PROJECT
TRIBUTARY WATERSHED SURVEYS
SAMPLING STATIONS

Poor Farm Brook

STA #1 : at staff gage behind Shrewsbury Industrial Park
STA #2 : at Route 70 bridge
STA #3 : at staff gage below Clark Street
STA #4 : at East Mountain Street, below golf course
STA #5 : at Hospital Drive (West Boylston)

Coalmine Brook

STA #6 : at Lake Avenue at gage
STA #7 : at Plantation Street
STA #8 : below culvert at Notre Dame convent entrance
STA #9 : confluence with I-290/Lincoln Plaza drain - Notre Dame property
STA #10: at culvert below I-290

Fitzgerald Brook

STA #11: at staff gage on Lake Avenue
STA #12: below Coburn Avenue

O'Hara Brook

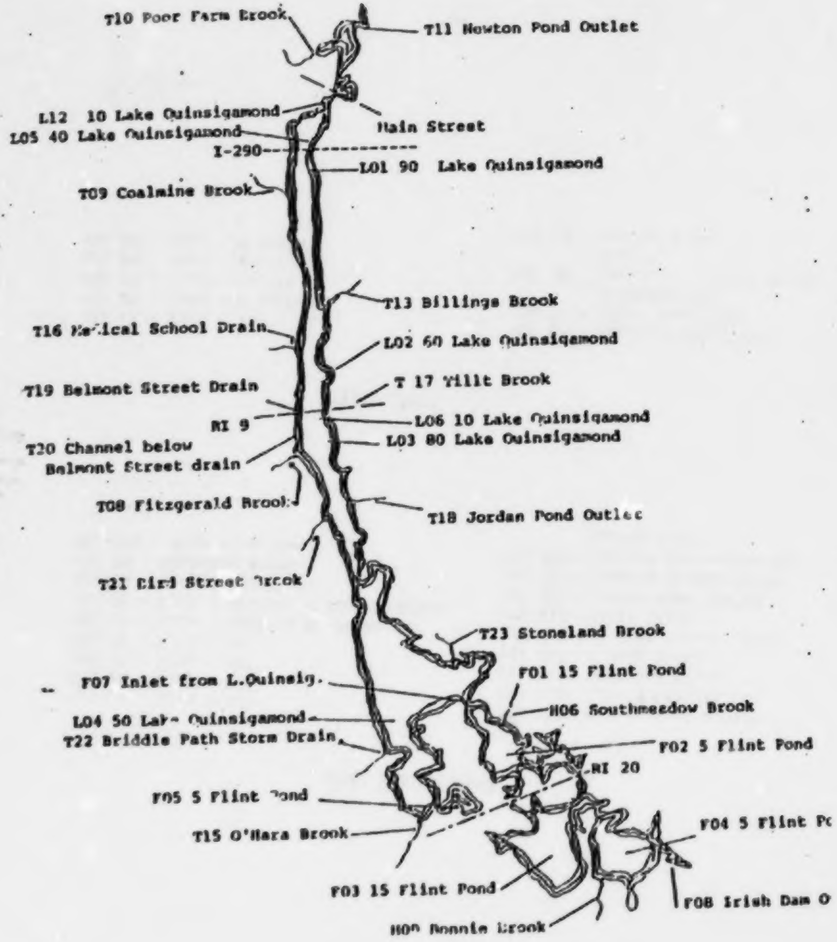
STA #13: at staff gage on culvert behind 17 Whitla Drive

Tilly Brook

STA #14: West Brook at Main Street
STA #15: Outlet of Mill Pond
STA #16: at culvert above Spag's parking lot
STA #17: at staff gage on Harvey Place drain

South Meadow Brook

STA #18: at Route 9
STA #19: at Oak Street between Delphen Rd. and Judick St.
STA #20: at staff gage at South Quinsigamond Avenue



LAKE AND TRIBUTARY SAMPLING STATION LOCATIONS

LAKE QUINSIGAMOND SEDIMENT SAMPLING STATIONS

Lake Quinsigamond at Deep Station #1

Lake Quinsigamond at Deep Station #2

Lake Quinsigamond at Deep Station #3

Lake Quinsigamond at Deep Station #4

Lake Quinsigamond above Lincoln Street

Medical School Drain

Channel below Belmont Street Drain

Mouth of Fitzgerald Brook

Mouth of Coalmine Brook

Confluence of Coalmine Brook and HDA culvert

Mouth of Poor Farm Brook

Flint Pond at Station #1

Flint Pond at Station #3

Flint Pond at Station #4

Open water in pond below South Meadow Brook

Bonnie Brook above railroad tracks, below railroad tracks, and at Creeper Hill Road

PROBLEM

A. Local Definition

During the 1950's, Lake Quinsigamond was by far the most heavily fished body of water in Massachusetts. During the average opening weekend of the fishing season the lake supported considerably more angling trips than that which the majority of Massachusetts' waters supported during the entire season. The tremendous fishing use of the lake was as a result of its good water quality and heavy stockings of rainbow, brown and brook trout by the Massachusetts Division of Fisheries and Game, supplemented by trout purchased with contributions from interested parties.

The urbanization of the lake basin resulted in a variety of water pollution problems becoming apparent during the 1960's. Fishing use of Lake Quinsigamond dropped off dramatically as a result of the reduced water quality and concomitant drastic reduction in the stocking program. Concern about the deteriorating water quality combined with the tremendous desire to utilize the recreational assets of the lake produced widespread concern for the future of Lake Quinsigamond. Consequently, over a several year period in the late 1960's and early 1970's, investigations of the water quality of the lake and its feeder streams were undertaken by state and local agencies, conservation groups, university departments and private citizens. These efforts were successful in defining the more conspicuous pollution sources and in providing water quality data.

The point sources of municipal and industrial pollution were recognized, and effective abatement measures implemented. Most significant among these was the establishment of the Upper Blackstone Water Pollution Abatement District and construction of its regional treatment plants at Millbury, discharging to the Blackstone River. This resulted in connection of most point sources in the Lake Quinsigamond Basin to a system which conveys the wastes southward and out of the basin. A major point source in the basin will be eliminated with the completion of a relief sewer by the City of Worcester.

As a result of the public's continuing concern over Lake Quinsigamond's water quality, and for the purposes of determining the magnitude of the nonpoint sources on lake quality in a Massachusetts lake, the Massachusetts Division of Water Pollution Control (MDWPC) selected Lake Quinsigamond for a comprehensive study during 1971. The eight month study included a regular sampling program of 30 lake and tributary stations, flow measurements of the tributaries, and special studies of photosynthesis, fish populations and lake sediments.

The 1971 study concluded that significant impact was being caused by urban runoff entering Lake Quinsigamond. Specific problems cited were the large quantities of nutrients and suspended solids carried in by urban runoff plus runoff-induced degradation of the lake's bacteriological quality. It was further concluded that intensive development of the drainage basin had accelerated the lake's natural aging process, and could limit the lake's future recreational value.

The findings of the 1971 Lake Study, plus the increasing conspiciousness of urban runoff as point sources were eliminated, provided the impetus for additional actions. Beach closures at Regatta Point on the lakeshore resulted in the construction of an earthen dam by the City of Worcester to reroute stormwater from Belmont Hill. Worcester also instituted an ongoing program, including television inspections, to detect illegal connections to storm sewers, which the City regards as a major problem. A baseline survey was also conducted in 1977 by MDWPC which indicated that there were some improvements in lake water quality. It is believed that these improvements are a result of the elimination of various point sources of pollution in the basin.

However, in spite of the abatement of point sources, survey data indicates that certain pollutional indices have shown little improvement over the abatement period. In particular, the trophic status of the lake has, by certain measures, shown little change. This is thought to be a result of the urban runoff nutrient and BOD loads, which have replaced the point source loads as the urbanization and point-source abatement have proceeded simultaneously. Substantial growth is projected for the basin, and the question of what the ultimate impact will be on the lake is one of extreme importance. Planning for recreational and aesthetic amenities in the region and public water supply is highly contingent on the answer.

B. Local Perception

The similarity of Lake Quinsigamond to other lakes in Massachusetts, from a technical standpoint, was a primary consideration in the State's selection of the project. Massachusetts can be divided into four major physiographic regions based on limnological factors. Lake Quinsigamond is centrally located in the largest of these regions, termed the acidic facies of the central and coastal areas. By far the most common type in the State, this facies is characterized by low pH, low total hardness, high iron, and high manganese. The general cause for these characteristics is the near absence of $CaCO_3$ in the rocks and sediments. Considering that the majority of the state's 2,859 lakes and ponds lie in these facies, the regional significance of knowledge gained on lakes of the general limnological type of Lake Quinsigamond is considerable.

Strong local commitment to Lake Quinsigamond has already been demonstrated by local expenditures of time and money in efforts to identify and abate pollution affecting the lake. In addition, the Lake Quinsigamond Commission, the Lake Quinsigamond Action Force of the Worcester Chamber of Commerce, and the Regional Environmental Council have all been involved in local and state efforts to clean up the lake.

PROJECT DESCRIPTION

A. Major Objective

The principle objective of the study is to develop a basin management program, in conjunction with the ongoing Clean Lakes project, which will result in the preservation and restoration of Lake Quinsigamond and its tributary streams, stressing in particular the water quality impacts of urban stormwater runoff.

Secondary objectives of the study are to develop information on the nature of urban runoff affecting a major urbanized lake basin. This information is to be transferred to other areas with similar problems and to those areas where it is still possible to avoid those problems. An additional objective is to develop information on stormwater pollution controls which can transferred to other areas.

In developing information on the nature of urban runoff affecting an urbanized basin, the State feels it's necessary to define the full range of existing and potential water quality problems caused by stormwater runoff and to understand the land use/beneficial use interrelations mediated by stormwater runoff. A full range of viable stormwater control alternatives will be defined to develop a sound basin management program.

B. Methodologies

The Lake Quinsigamond NURP project has been divided into two distinct phases, the first of which took place during the first year. The first year effort was intended to define the full range of existing and potential water quality problems in the Lake Quinsigamond basin and to gain a clear understanding of the pollutant contibutions from different land uses.

Before a sampling methodology was developed, a preliminary assessment of stormwater loads was performed using models.

The purpose of the screening was twofold. First, it provided a basis for evaluating the average annual stormwater pollutant load to the lake and what percentage of the total annual pollutant load to the lake might be attributed to urban runoff. The screening also assisted in the selection of stormwater sampling stations.

Using the information developed through the screening methods, a stormwater sampling program was identified. This program was designed to provide sufficient information on the quality and mass loadings of pollutants discharged to Lake Quinsigamond to allow correlations to be made between land use, storm events, and resultant short and long term impacts on lake water quality.

The data collected in the monitoring effort will be input into the same models used for that screening effort to come up with a refined set of land use-based pollutant generation coefficients and an analysis of the impacts of stormwater runoff on lake water quality.

This information on the impacts of stormwater runoff will be combined with the criteria associated with the water quality goals for the lake to determine the level of pollutant reduction required of stormwater runoff that will allow the Lake to meet its assigned water quality classification.

Using other information on historical rainfall, hydrologic design criteria such as design storm volume, washoff depth, etc. will be established. A range of control alternatives including structural, non-structural and management controls capable of meeting the design criteria will be defined. This range of control alternatives will be used in the development of a stormwater management plan for the watershed.

C. Monitoring

In order to augment the existing data base and to more clearly establish cause - effect relationships between wet weather events and in-lake water quality impacts on both a short and long-term basis, and expanded sampling program for the lake and its tributaries was jointly developed by the Massachusetts Division of Water Pollution Control 314 staff and DEQE/NURP staff. Biweekly sampling was conducted at all in-lake stations and natural tributaries from the months of April to November 1980. For the in-lake stations, chemical samples were collected at the surface, thermocline, 50 feet and bottom intervals. Dissolved oxygen and temperature measurements were made at 10 foot intervals in order to determine the rate of oxygen depletion in the hypolimnion and further define chemical transformations and trends during the lake's period of stratification. Stage/rating curves were developed for the major tributaries to the lake. A survey of selected major tributaries was conducted by the Worcester Department of Public Health and NURP staff. This program is to aid in characterizing and defining trends in water quality as they relate to land use and other tributary watershed characteristics and in establishing water quality baselines for the tributaries. Sampling at these tributaries was conducted on a monthly basis from September 1980 to July 1981. Sediment samples were also collected to determine the nutrient and heavy metals content.

Primary and Secondary Stormwater Sampling Program

Stormwater sampling sites were located at six primary sites (P1-P6) and nine secondary sites (S1-S9). Automatic water quality sampling devices and continuous flow recording devices were located at the primary locations. The secondary locations were selected for manual sampling and gaging with the exception of Poor Farm Brook (S-9) which had a continuous flow recording device for part of the sampling period.

The following is a list of sampling stations. Primary sites are designated by "P".

Designation	Location
P1	Storm drain discharge to Jordan Pond (Shrewsbury at Lakewood Drive and Edgewood Avenue)

P2	Rt. 9 manhole (within Regatta Point fence at Police Station upstream of Belmont St. outfalls to the lake, Worcester side).
P3	Manhole on Locust Ave. (Worcester).
P4	Fitzgerald Brook discharge to the Lake across from Anna St. (Worcester).
P5	Coal Mine Brook at Notre Dame Convent (Worcester).
P6	Tilly Brook at Harvey Place Manhole (Shrewsbury).

There are ten secondary stormwater sampling stations

A. Poor Farm Brook at Rt. 70
B. Poor Farm Brook at Mouth
C. Coalmine Brook at NDC
D. Coalmine Brook at Plantation St.
E. Coalmine Brook at Mouth
F. South Meadow Brook at Oak St.
G. South Meadow Brook at Mouth
H. O'Hara Brook at Whitla Ave.
I. Billings Brook at N. Quinsigamond
J. Bonnie Brook at Creeper Hill Rd.

Catchment divisions were determined for all sampling locations and for the model cells which cover the entire watershed. Land uses were assessed for each catchment division.

Water quality, flow and rainfall records were collected over a period from June to December, 1980. Specific collection schemes were designed to cover various types of composite and discrete samples.

Equipment

Each primary station was equipped with continuous automatic flow (liquid level) recording devices. Each site designated as a secondary station had sampling and flow gaging conducted by manual means.

Water quality samples were taken at the primary stations using Manning automatic samplers collecting discrete and sequential samples over a specified period of time. The sampler used a vacuum pump to minimize agitation of the sample. It was driven by standard 12 volt batteries. Samplers were set to initiate sampling at the first significant increase in flow caused by storm runoff.

D. Controls

Several alternative control strategies will be evaluated using modeling techniques.

NATIONWIDE URBAN RUNOFF PROGRAM

MASSACHUSETTS DEPARTMENT OF
ENVIRONMENTAL QUALITY ENGINEERING

MYSTIC RIVER, WATERSHED, MA

REGION I, EPA

INTRODUCTION

The Aberjona River Basin is located to the north of Boston, Massachusetts and comprises the largest tributary area to the Mystic River watershed. Aberjona River empties into the Upper Mystic Lake which in turn becomes the headwaters of the Mystic River. During the two decades from 1950 to 1970 this area underwent a tremendous urban expansion. Population increased by approximately sixty percent and the total acreage under some form of urban land use climbed to nearly fifty percent of the available land area. Although the pace of urbanization and population growth has slackened somewhat, it is estimated that nearly sixty percent of the drainage area to the Upper Mystic Lake will be developed by the mid 1990's.

At present the water quality conditions throughout the Aberjona River system and in the Upper Mystic Lake are generally below the standards assigned by the Massachusetts Division of Water Pollution Control and fall short of the quality desired by the local populace. As the level of urbanization and the area population increase, the demand for improved water quality conditions and expanded recreational opportunities will continue to grow. Recent and on-going efforts at the state and local level have been directed towards eliminating the adverse impacts of point source discharges and past waste dispoal practices. The effects of urban runoff on water quality in the study area have not yet been addressed and remain a major factor prohibiting the full realization of recreational opportunities within the urban watershed.

PHYSICAL DESCRIPTION

A. Area

The Mystic River basin is located to the north of Boston and covers approximately 62 square miles. The Upper Mystic Lake Watershed, the study area, covers 28 square miles in the upper basin. Most of this area, 25 square miles, is drained by the Aberjona River and its tributaries; the remaining area drains directly into the Upper Mystic Lake.

The Upper Mystic Lake itself has two shallow forebays, 6 to 8 feet in depth, with a joint surface area of 40 acres, which flow into the main body which has a surface area of 126 acres and a maximum depth of approximately 90 feet. The lake is a major recreational area serving residents within the watershed and from nearby communities. The Metropolitan District Commission maintains a swimming facility - "Sandy Beach" - in the northeastern corner of the main body. There is also a private swimming facility at the Medford Boat Club near the outlet. Boating is also a popular activity. Fishing was enjoyed in the past but the lake quality is no longer suitable for game fish.

The Mystic River basin in characterized by long, cold winters and short to medium length summers with rainy, humid, warm periods. Average annual precipitation is about forty-three inches and is distributed through the four seasons in approximately equal increments.

Historical information indicates that storms with relatively long duration and moderate intensity have more pronounced effects on the Mystic basin than short duration, high intensity storms.

B. Population

In 1975, the population of the Upper Mystic Lake Watershed was 640,000. During the two decades from 1950 to 1970 this area underwent a tremendous uran expansion. Population increased by approximately sixty percent and the total acreage under some form of urban land use climbed to nearly fifty percent of the available land area. Although the pace of urbanization and population growth has slackened somewhat, it is estimated that nearly sixty percent of the drainage area to the upper Mystic Lake will be developed by the mid 1990's.

C. Drainage

The Mystic River Basin extends northeast from Boston Harbor and is bordered on the west by the Shawsheen River Basin, on the north by the Ipswich River Basin, and on the south by the Charles River Basin. The topography of the basin, which was formed by the east glacier about ten thousand years ago, is predominately rolling hills and flat lands containing swamps, but includes some steep and rocky areas. Elevations range from sea level to a few hundred feet. Above the Amelia Earhart Dam, the basin encompasses a drainage area of 61.9 square miles, including 25 square miles which is drained by the Aberjona River.

Upper Mystic Basin

The Aberjona River Basin covers the northern half of the Mystic Basin and includes the true source of the Mystic river, although the name "Mystic" is not applied to these waters until they pass through the Mystic Lakes. The Aberjona River has its origins in a marshy area to the north of Reading Center and then flows in a southerly direction towards Woburn. After crossing Route 129 in Reading the stream enters a swampy area and emerges as two separate branches. These two branches are re-united when the Aberjona is channelized through the commercial/industrial area currently undergoing re-development in the vicinity of the Old Mishawum Lake just north of Route 128.

Halls Brook and its tributary, Willow Brook, rise in marsh land west of the Aberjona. Halls Brook first flows north until its confluence with Willow Brook. It then turns east-northeast until it reaches New Boston Street in Woburn, where it again turns and flows southeast until its confluence with the Aberjona River. The drainage area of Halls Brook is 2.9 square miles of generally mild topography with some swampy areas in the upper reaches.

Halls Brook and the Aberjona River formerly flowed into the Mishawum Lake but the recent construction in that area has altered that drainage pattern. Mishawum Lake has been largely filled and replaced by Halls Brook holding pond; Halls Brook empties into this pond. The Aberjona has been routed around this pond and now joins Halls Brook at the pond outlet immediately north of Mishawum Road.

Below Halls Brook the Aberjona flows south, passes under Route 128 and Olympia Avenue and then enters a marshy area extending through Cedar Street and down to Hill Street. This marshy area was formerly a large cranberry bog. The marsh gives way to a well-defined stream channel and flows past Washington Street and Montvale Avenue, shortly after which Sweetwater Brook joins the river from the east.

Sweetwater Brook, which has a predominantly urban drainage area of 2.3 square miles, rises in a marshy area adjacent to Main Street in Stoneham. It flows south for a short distance and then through an underground pipe for about 2000 feet. After leaving the pipe Sweetwater Brook flows southwest in an open channel until just east of Interstate Route 93, from there the brook is channeled through a manufacturing area and into the Aberjona River.

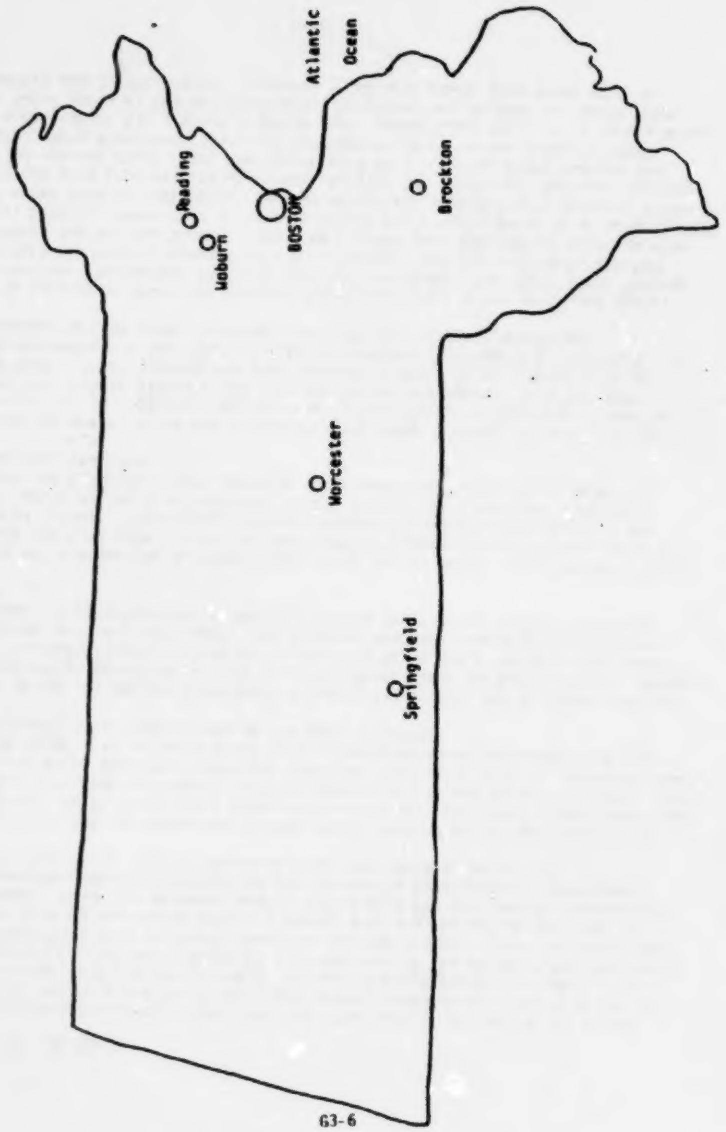
Below Sweetwater Brook the Aberjona River continues to the south and enters Winchester. Throughout the upper part of Winchester, the river flows through a relatively natural channel past Cross Street, Washington Street, the B&M railroad and Swanton Street. There is a small pond immediately upstream from Cross Street. Downstream of Swanton Street the river travels in an open channel for a few hundred feet until reaching Winchester High School's athletic field. Aberjona pond once existed where the athletic field is now. The pond has been filled and the river flows through three 7-foot diameter pipes beneath the field. Horn Pond Brook joins the Aberjona River below the athletic field. Horn Pond Brook has a total drainage area, above Wedge Pond, of 10 square miles. The outer parts of the Horn Pond Brook watershed are drained by Shaker Glen, Cummings and Sucker Brooks. Cummings Brook and Shaker Glen Brook rise in marshy areas to the north and west of Horn Pond, respectively. Cumming's Brook meanders in a southerly direction, while Shaker Glen Brook generally flows northwest until its confluence with Cummings Brook to form Fowle Brook. Fowle Brook flows due east where it empties into Horn Pond. Sucker Brook rises to the south and flows northeast to Horn Pond.

Horn Pond covers a surface area of roughly 120 acres and is used for limited recreational purposes and as a water supply source for the Town of Woburn. In the recent past its capacity was increased by raising its normal water surface approximately six feet. Horn Pond discharges through a weir structure into Horn Pond Brook, which then flows in a southeasterly direction through Wedge Pond to the Aberjona River.

Below its confluence with Horn Pond Brook, the Aberjona enters Judkins Pond and Mill Pond in Winchester Center. The outlet of Mill Pond is configured as a semi-circle step spillway that falls approximately six feet. The river continues to travel in a southerly direction to the United States Geological Survey guage located a short distance downstream. An elevation change of approximately ninety feet is recorded over a distance slightly more than eight miles from the headwaters in Reading to Upper Mystic Lake in Winchester. As the Aberjona River nears the end of its length it makes a final bend to the west, gaining depth and width as it enters the Upper Mystic Lake.

D. Sewerage System

The upper Mystic Lake watershed is served entirely by separate storm sewers.



THE STATE OF MASSACHUSETTS

PROJECT AREA

I. Catchment Name - EOPA (36" storm drain outfall draining a 50 acre residential area).

A. Area - 50 acres.

B. Population - 240 persons.

C. Drainage - Station is located at end of 36 inch reinforced concrete pipe. The area drained is low density residential. There are sidewalks, well-groomed lawns, and trees. The land is moderately sloped towards the monitoring station and the streets are relatively clean.

D. Sewerage - Drainage area of catchment is 70% separate storm sewers and 20% curbs and gutters. 80% of this area has swales and ditches. 30% is not separately sewered. There are no combined sewers in the area. Streets consist of 2.5 miles of asphalt.

E. Land Use

50 acres (100%) is .5 to 2 dwelling units/acre.

8 acres (16%) is impervious.

II. Catchment Name - EOPB (manhole installation in 30" pipe draining an 18 acre office park).

A. Area - 18 acres

B. Population - 0 persons live in the catchment

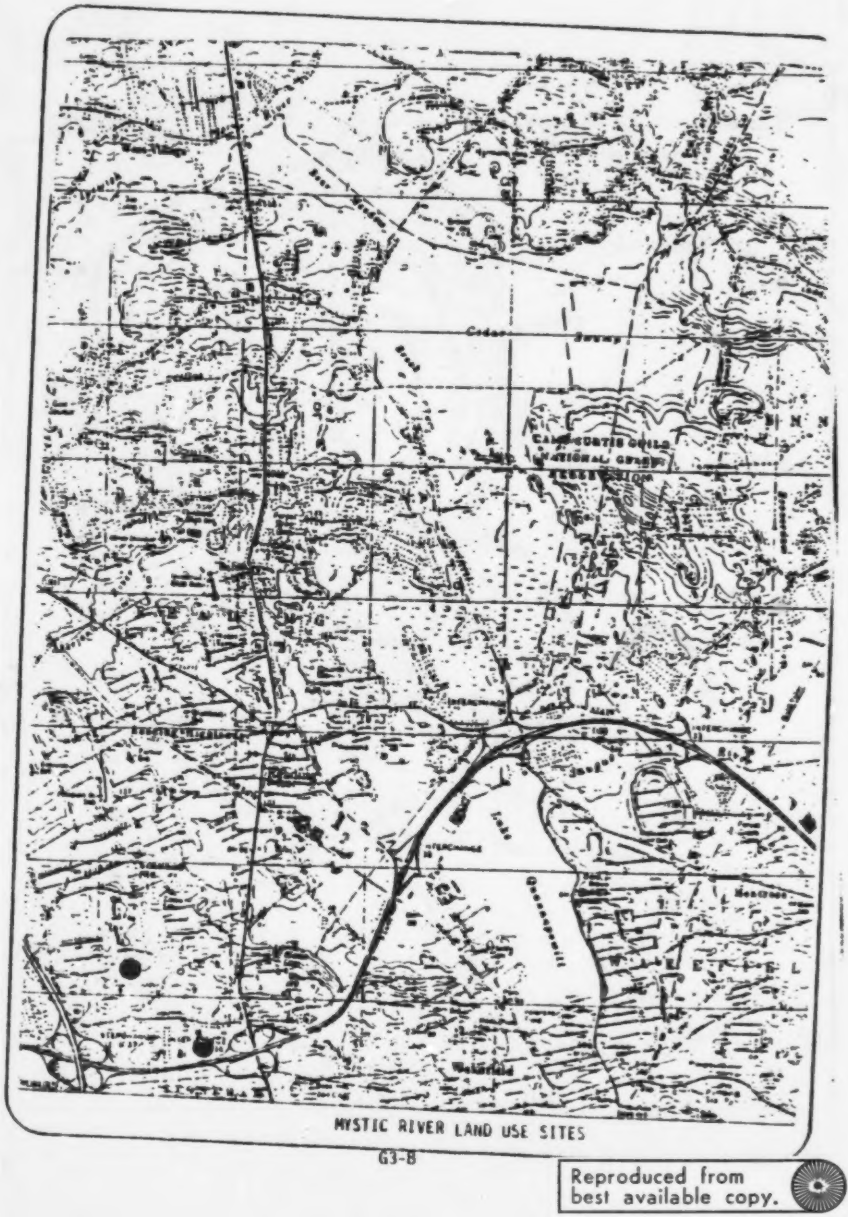
C. Drainage - Station is located at end of 30 inch reinforced concrete pipe draining an 18 acre office park. There are well-groomed lawns, shrubs, and trees throughout the park. Basin has relatively steep slope towards station.

D. Sewerage - Drainage area of catchment is 70% separate storm sewers and 30% with no sewers. There are no combined sewers in the area. Streets consist of 2.5 miles of asphalt.

E. Land Use

18 acres (100%) is light industrial.

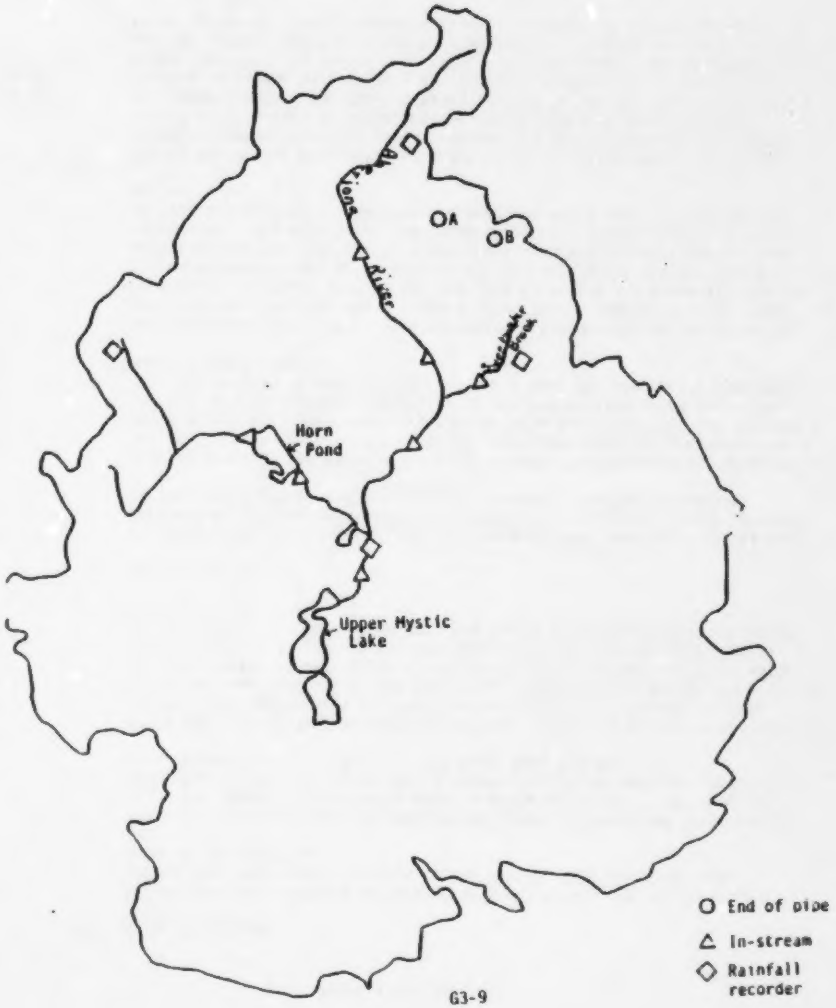
12.5 acres (69%) is impervious.



MYSTIC RIVER LAND USE SITES

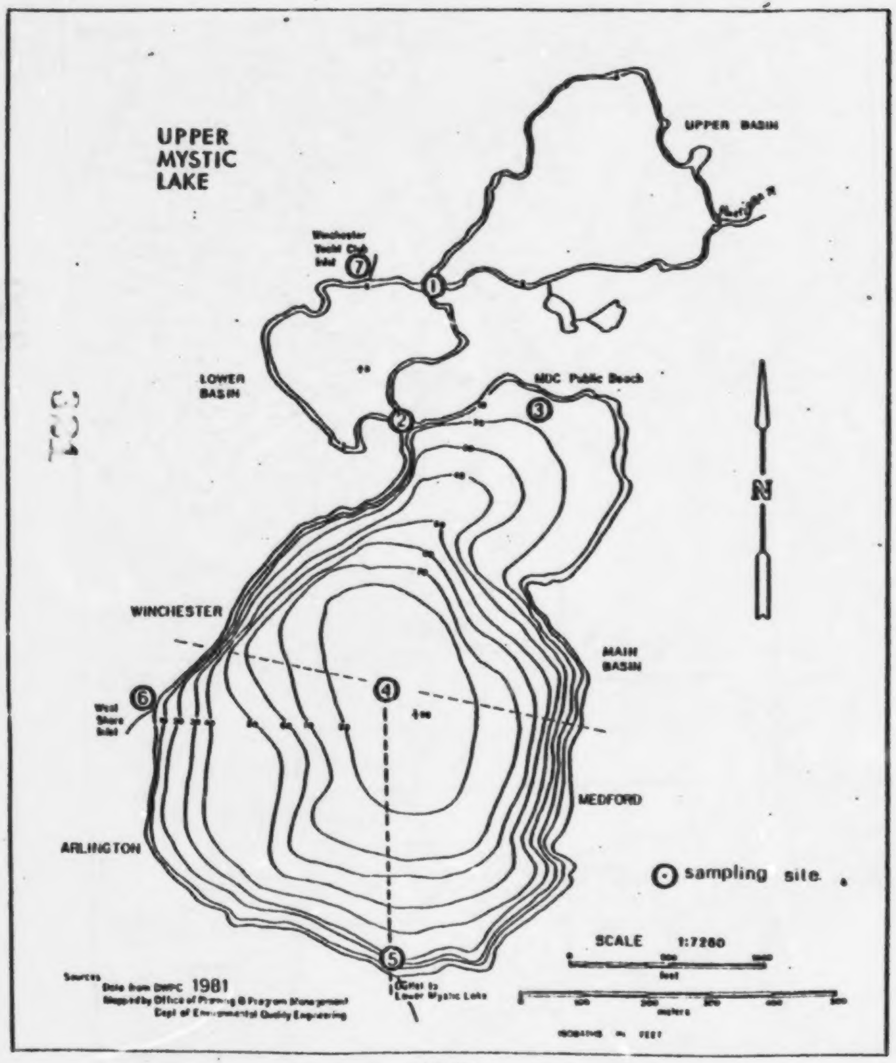
G3-8

Reproduced from best available copy.



G3-9

MYSTIC RIVER WATERSHED



PROJECT DESCRIPTION

A. Major Objectives

The project was designed to build upon the existing data base to fully define the urban runoff problem in the Mystic River Basin and work towards its solution.

The major objectives are to identify the characteristics of urban runoff and their impacts on receiving water quality in the Aberjona River and Upper Mystic Lake and to recommend control strategies and management practices needed for restoration of the Upper Mystic Lake.

There are several intermediate objectives. These are to assess the relative importance of pollutants carried by urban runoff in relation to other pollution sources, to evaluate the costs, effectiveness and practicality of various procedures suggested as a means of improving the receiving water quality, and to illustrate how the data collected and the knowledge gained in this effort can be applied to urban runoff problems in other areas of the region and nation.

B. Methodologies

To fulfill the goals outlined for the program, the hydrologic system was broken down into several similar subsystems for analysis, namely: precipitation, pollutant generation, stream transport, and lake processes.

Precipitation is the basic driving for runoff, infiltration and streamflow. The statistical characteristics of the long-term observed precipitation at local gauges were determined describing storm depth duration and intensity and the interval between storms, using a rainfall simulation logarithm. This information is used as rainfall input data for the runoff simulation model discussed below.

The pollutant generation subsystem uses the STORM model to represent the accumulation, washoff, and transport of pollutant species from the land surface of the study area to the Aberjona River and its major tributaries. The Upper Mystic Lake watershed was divided into eight sub-basins for analysis with the contibuting acreage defined in terms of five land use categories. The results of the STORM simulation give a long-term record of flow and pollutant load into the Aberjona River from the various sub-basins.

During the stream transport component of the analysis the existing and potential wet weather pollution problems are identified with the urban runoff contribution to these problems separated from other factors.
To accomplish this the RWQM is being applied to the Aberjona River with the 6 mile system divided into 12 reaches. A number of pollutants are being simulated, including BOD, NBOD, D.O., phosphorus and coliform. The results of this simulation can be expressed as loadings to the Upper Mystic Lake. RWQM will also be used to evauate a number of control options.

The objectives of the lake processes component are:

1) to increase understanding of the chemical, physical and biological processes which control water quality conditions in the Upper Mystic Lake (UML), relating those conditions to water uses of concern;

2) to assess the contribution of urban runoff relative to other sources; and

3) to predict lake quality response to various control options.

The analysis includes a number of key factors including: hydraulic flushing rates and retention time; in-lake circulation patterns; relative thermal resistence to mixing; oxygen distribution and depletion; in-lake pollutant cycling; trophic state; buffering capacity; population dynamics, and; bacteriology.

The analysis will compare wet-weather response conditions to baseline or dry-weather conditions. Lake conditions that can be controlled through application of urban runoff and lake restoration practices are being determined.

C. Monitoring

Wet-weather sampling at end of pipe and instream stations was conducted by the selected consultant. The existing sampling programs of the Department of Environmental Quality Engineering and the Metropolitan District Commission were modified to meet the project needs.

The end of pipes sites represent major land use types in the watershed. The instream sites segment the Aberjona into subbasins for the runoff model and reaches for the river quality. The sites for in-lake sampling are shown on Figure 2. Precipitation is being monitored at four sites.

The sampling program on the lake includes wet weather physical/chemical sampling 24, 48 and 72 hours after the end of the storm event, dry weather physical/chemical sampling, circulation studies, benthic sampling, phytoplankton and zooplankton surveys, fish population surveys, and fish flesh.

The lake sampling program includes 5 inlake stations and two tributary stations. The inlake sites are located between the forebays and main basin, at the beach, at the deephole and at the outlet and are designed to track water quality conditions throughout the system.

The data collection strategy for the end of pipe and instream sites is presented in Table 2.

Equipment

Precipitation is being monitored using Weather Measure, Inc. P521 event recorders, P501-I tipping ticket bucket rain gauges and Balfour gauges. At the end of pipe and instream stations, permanent installations are maintained consisting of Manning S4040-2 discrete samplers and Manning UTL 2102A ultrasonic level recorders. Lake samples were taken manually at various time intervals using a Kemmerer sampler. In the shallow upper portions of the Upper Mystic Lake where maximum depths are less than 15 feet, samples were taken from two depths. In the main body of the lake, where depths up to 82 feet may be encountered, samples were taken at three depths in five locations.

D. Control

Evaluation of control technologies and management strategies will be carried out using the same package of simulation models as described above.

TABLE 2: Sampling Strategy Summary - End-of-Pipe/Instream

Site	Description	Equipment	Sampling	Composition (Chemistry)
EOP A	36" storm drain outfall draining a 50 acre residential area	flow: automatic liquid level sonic sensor quality: modified Manning automatic sampler: Field measurement of bacteria, D.O., and temperature.	chemistry duration - 6 hours frequency - 5 min. bacteria/D.O./temp. 5 samples-3 on rising limb, 2 on recession limb.	baseline and 3 flow weighted composites based on total runoff volume - first 25%, second 25%, last 50%.
EOP B	outfall installation in 30" pipe draining an 18 acre office park	same as above	same as above	
IS 1	Aberjona River at Mishawum Rd. with an upstream drainage area of 4,157 acres which isolates the impacts of past industrial waste disposal practices in the upper basin	same as above	chemistry duration-24 hours frequency-15 min. bacteria/D.O./temp. 5 samples-3 on rising limb, 2 on recession limb.	baseline on 4 flow weighted composites based on total river volume-first, second, third and fourth 25%.
IS 2	Aberjona River at Mill Street, approximately 2 1/2 miles downstream of IS 1 with the intervening reach characterized by a shallow swampy area.			
IS 3	Sweetwater Brook at Maple Street which drains 1490 acres and is the most heavily urbanized sub-basin within the study area.			
IS 4	Aberjona River at Washington Street 2 1/2 miles above IS 6.			
IS 5	Outlet of Horn Pond approximately 1.1 miles above the confluence of Horn Pond Brook (6272 acre sub-basin) and the Aberjona.			
IS 6	Aberjona River at the USGS gauge located approximately 1/2 mile above the Upper Mystic Lake.	quality: same as above flow: 15 minute stage readings are recorded at the USGS gauge.		

PROBLEM

A. Local Definition

The extensive residential development and ever-increasing business and industrial growth which have occured in the basin, have given rise to many water quality problems which have totally or partially impaired water related recreational opportunities in the basin.

The Upper Mystic Lake was used for public water supply until 1895 and supports game fish and outdoor recreational activities such as swimming, sailing and boating. Although there is no present need to utilize the lake for water supply purposes, the importance of its recreational potential has grown tremendously. Sail-boating is very popular and the Metropolitan District Commission maintains a park and beach/swimming area. Unfortunately, the water quality conditions in the Mystic Lakes have deteriorated and game fish can no longer be supported. At present the Upper Mystic Lake suffers from a variety of water quality problems. Nitrogen concentrations are approaching toxicity levels for fish and other aquatic organisms; this may have contributed to the failure of previous attempts to stock the lake with trout. Phosphorus is far less abundant but concentrations are still in the range of those suggested as sufficient for eutrophication. Low transparency may be a cause for the present absence of severe algal blooms. Although water quality improves somewhat from influent to effluent, the Upper Mystic Lake is still in violation of its Class B standard.

The Aberjona River is considered to be the major source of nitrogen and zinc, and mainly responsible for existing eutrophic conditions in the Upper Mystic Lake. Stormwater discharges, industrial discharges, combined sewer overflows of raw sewage, landfill leachate and wetlands alteration, combined with low flow problems, have prevented the use of the river for any form of contact recreation.

B. Local Perception

Because of these water quality problems and a recognition of the value of the Basin's waterbodies, many resources have been expended at the local, regional, state, and federal levels for the study and control of the various water pollution sources. A brief summary of the efforts pertaining to the Aberjona River Basin and the Upper Mystic Lake are presented in the following paragraphs.

The Massachusetts Division of Water Pollution Control had conductd 1 week long intensive surveys in 1967-1973, of the Aberjona River, Mystic River, and tributaries. These were in-stream, usually dry-weather surveys.

The MDC also has in-stream water quality data for the Basin from 1975 to 1978, bi-monthly in spring/summer months; monthly in winter months. These surveys basically offer dry-weather data but some wet-weather in-stream data are available from these surveys.

The 208 program, undertaken by the Metropolitan Area Planning Council (MAPC), investigated storm-related (combined sewer overlfows and urban runoff) water quality problems in the Mystic River Basin. Under this effort, the stormwater collection systems in the Mystic Basin communities were inventoried and mapped. An attempt was then made to quantify the water quality impacts of these collection systems in order to identify the most significant systems and discharges.

The DWPC completed wet-weather surveys in the fall of 1977. Data were collected on six stations in the basin, 5 of which were storm drains and 1 was a combined sewer overflow, for the first four hours of a storm.

The Upper Mystic Lake has also been studied in detail. In 1974-1975, the DWPC conducted a one-year intensive study of the Upper Mystic Lake with monthly samplings at its inlets, deep hole, and outlet. The study focused on the limnology of the lake and the causes of its eutrophic state.

The above survey is indicative of the importance of this urban watershed and of the attention that has been directed towards various water resource problems in the Aberjona River and Upper Mystic Lake watersheds.

NATIONWIDE URBAN RUNOFF PROGRAM

LONG ISLAND REGIONAL PLANNING COMMISSION

LONG ISLAND, NEW YORK

REGION I, EPA

Reproduced from best available copy.

INTRODUCTION

Groundwater is the sole source of fresh water for the more than 2.7 million residents of Nassau and Suffolk Counties on Long Island, N.Y. (Figure 1). Under natural conditions, the groundwater reservior is recharged only by local precipitation seeping from the land surface to the water table. Since the 1920's, when Nassau County began to experience rapid urbanization, the construction of highways and parkways, houses, shopping centers, industrial parks, and street and sidewalks in areas that had been farmland has continuously reduced the amount of land surface through which precipitation can infiltrate to the water table. After urbanization, storm runoff from the paved surfaces was carried to coastal waters through storm sewers, which resulted in a substantial loss of recharge to the groundwater resevoir.

When Nassau County recognized that natural recharge was being lost, it began, in 1935, to excavate large basins to impound stormwater so that the water could infiltrate to the groundwater reservoir through the permeable sand and gravel beds that underlie Long Island. The use of stormwater basins not only helped to conserve storm runoff and to augment the groundwater supply, but also eliminated the need for long, costly trunk storm sewers to carry runoff to coastal waters. The concept was adopted throughout Suffolk County some years later. In spite of these efforts, there remain significant areas not served by recharge basins, and, therefore, relatively large quantities of runoff are still discharged to bays.

Investigations of the results of stormwater runoff management practices conducted during the Long Island 208 Study identified major deleterious effects of runoff upon surface waters and possible significant impacts upon groundwater. With respect to surface waters, the major concerns are the potential impacts upon use of the embayments for contact recreation, a use presently widespread, and both existing and future closures of shellfish areas for health reasons. With respect to groundwater, a major concern is the suspected organic chemical contamination of the drinking water supply from runoff.

PHYSICAL DESCRIPTION

A. Area

Long Island, the eastern-most part of New York State, extends east-northeastward roughly parallel to the coastline. The study area, Nassau and Suffolk Counties, is bounded on the narth by Long Island sound, on the east and south by the Atlantic Ocean, and on the west by Queens County which is one of the five boroughs of New York City (Figure 1). The primary land use is residential but significant portions of the two counties is given to industrial and commercial uses. Farming is also a major land use, particularly in the central and eastern sections of Suffolk County. The inland fresh waters, particularly in Suffolk County, have an abundance of trout and other important sport fish. Estuarine marshes and the off-shore waters abound in a variety of shell- and finfish.

B. Population

Nassau and Suffolk Counties occupy one-sixth of the land area of the New York Metropolitan Region, and have been two of the fastest growing counties in the United States since the end of World War II. In 1960, the combined Nassau and Suffolk population of two million persons was one-eighth of the total Regional population of sixteen million. The present population of the bi-county area is in excess of 2.7 million people.

C. Drainage

Long Island is underlain by a thick southward-dipping wedge of rock materials that consist mainly of sand, silt, clay, and gravel. These loose materials are underlain by dense crystalline bedrock that does not store or transmit significant quantities of water. The groundwater reservoir is within the loose (unconsolidated) materials above bedrock and ranges in thickness from zero to northern Queens County, were bedrock is exposed to more than 2,000 feet in south-central Suffolk County. Of the total precipitation on the island (which averages about 44 inches per year), approximately half or 600 million gallons per day recharges the groundwater reservoir in Nassau and Suffolk Counties. Natural runoff discharged to surface waters accounts for only 5-10 percent of the precipitation, but in urbanized areas of the two counties runoff is much greater. As a result of the topography, all the southward flowing streams have gentle gradients that average about 10 feet per mile throughout most of their reaches. The northward flowing streams generally have steeper gradients that average about 20-40 feet per mile.

D. Sewerage System

Because of differences in the degree of development in the two counties, and the inherently fixed nature of the existing Nassau system, treatment emphasis differs not only by the hydrogeologic zone but also by administrative area. In Nassau, the major options concern treatment plant locations and effluent disposal; in Suffolk, the major options concern an identification of those areas that should be sewered as well as the siting of treatment facilities and effluent discharges.

In addition, Nassau and Suffolk are discussed separately because their municipal wastewater treatment needs differ. Nassau County is highly developed; according to the 208 population estimates, the county population is approximately 96 percent of saturation or zoned capacity, and is projected to reach 98 percent by the year 1995. Suffolk's population, on the other hand, is currently at 52 percent of saturation and is expected to increase to 71 percent by 1995. Nassau County has 23 existing domestic wastewater treatment facilities, and major new construction is not anticipated except where expansion and upgrading of existing facilities is necessary. Suffolk County has 105 small domestic treatment facilities in operation, and one major facility (30 MGD) under construction. Nassau's domestic treatment facilities are generally large scale, treating up to 60 million gallons per day (MGD), but a typical Suffolk County domestic wastewater treatment plant treats less than one MGD, with the largest treating only approximately two MGD.

Surface water quality considerations also dictate different approaches in the Bi-county Region. Marine water quality in Nassau County and western Suffolk is influenced by the effects of New York City discharge. In eastern Suffolk, agricultural uses impact river and bay quality. A final reason for separate consideration of the two counties concerns their degree of urbanization: Nassau and western Suffolk Counties are highly urbanized, while eastern Suffolk is essentially rural and agricultural in nature.

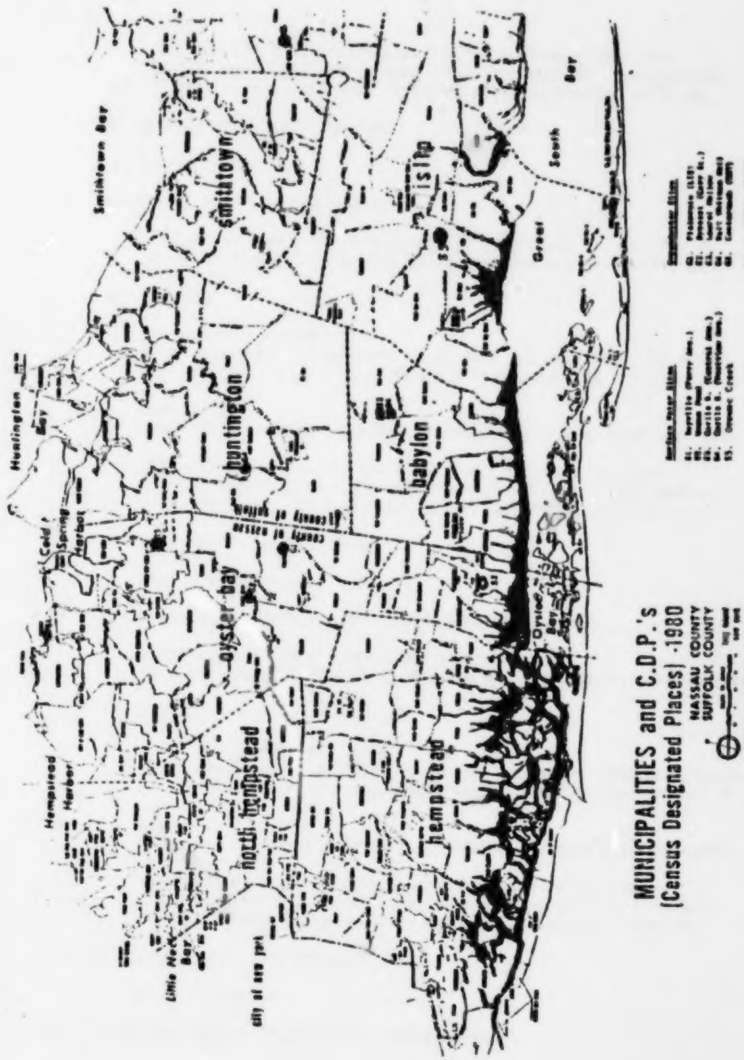


Figure 1 - Project Area and Sampling Sites

PROJECT AREA

I. Catchment Name - Bayville (Perry Ave.)

A. Area - 65.6 acres.

B. Population - 612 persons.

C. Drainage - This catchment area has a representative slope of 40 feet/mile, 50% served with curbs and gutters. The storm sewers approximate a 40 feet/mile slope and extend 3500 feet.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers.

Streets consist of 3.9 lane-miles of asphalt, 60% of which is in good condition and 40% of which is in fair condition.

E. Land Use

65.6 acres (100%) is 2.5 to 8 dwelling units per acre urban residential of which 9.8 acres (15%) is impervious.

II. Catchment Name - Unqua Pond (Massapequa)

A. Area - 298.5 acres.

B. Population - 9492 persons.

C. Drainage - This catchment area has a representative slope of 20 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 20 feet/mile slope and extend 2800 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 46.6 lane-miles of asphalt, 100% of which is in good condition, and 3 lane-miles of concrete, of which 100% is in good condition.

E. Land Use

253 acres (85%) is 2.5 to 8 dwelling units per acre urban residential, of which 40 acres (16%) is impervious.

15 acres (5%) is Shopping Center of which 14 acres (93%) is impervious.

30 acres (10%) is Urban Parkland or Open Space of which 4 acres (13%) is impervious.

III. Catchment Name - Carlls River Street Sweeping

A. Area - 73 acres.

B. Population - 939 persons.

C. Drainage - This catchment area has a representative slope of 1.7 feet/mile, 81% served with curbs and gutters. The channel approximates a 1.7 feet/mile slope and extends 4725 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 9.5 lane-miles of asphalt, 90% of which is in good condition, 7% of which is in fair condition, and 3% of which is in poor condition.

E. Land Use

73 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 14.5 acres (20%) is impervious.

IV. Catchment Name - Carlls River Street Sweeping Control

A. Area - 64 acres.

B. Population - 925 persons.

C. Drainage - This catchment area has a representative slope of 1.7 feet/mile, 93% served with curbs and gutters. The channel approximates a 1.9 feet/mile slope and extends 2775 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 7.98 lane-miles of asphalt, 90% of which is in good condition, 7% of which is in fair condition, and 3% of which is in poor condition.

E. Land Use

64 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 13 acres (20%) is impervious.

V. Catchment Name - Orowoc Creek

A. Area - 188 acres.

B. Population - 2,260 persons

C. Drainage - This catchment area has a representative slope of 22 feet/mile, 85% served with curbs and gutters. The channel approximates a 22 feet/mile slope and extends 1,700 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 16.45 lane-miles of asphalt, 86% of which is in good condition, 10% of which is fair condition, and 4% of which is in poor condition.

E. Land Use - 154 acres (82%) is 2.5 to e dwelling units per acre urban residential, 14 acres (8%) is urban institutional, and 18 acres (10%) is the stream channel. 26.3 acres (14%) is impervious.

VI. Catchment Name - Huntington (Parking Lot)

A. Area - 39.19 acres.

B. Population - 0 persons.

C. Drainage - This catchment area has a representative slope of 84.5 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 58 feet/mile slope and extend 1400 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 27 lane-miles of asphalt of which 100% is in good condition.

E. Land Use

39.19 acres (100%) is Shopping Center, of which 39.19 acres (100%) is impervious.

VII. Catchment Name - Plainview (Highway)

A. Area - 190 acres.

B. Population - 0 persons.

C. Drainage - This catchment area has a representative slope of 119 feet/mile, 85% served with curbs and gutters and 15% served with swales and ditches. The channel approximates a 206 feet/mile slope and extends 2500 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Street consist of .9 lane-miles of asphalt, 100% of which is in good condition, and 1.5 lane-miles of concrete, of which 100% is in good condition.

E. Land Use

178.1 acres (94%) is urban parkland or open space.

11.9 acres (6%) is Urban (other), of which 11.9 acres (100%) is impervious.

VIII. Catchment Name - Syosset (Medium Density Residential)

A. Area - 28.2 acres.

B. Population - 238 persons.

C. Drainage - This catchment area has a representative slope of 42.6 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 42 feet/mile slope and extend 2100 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 2.45 lane-miles of asphalt, 100% of which is in good condition.

E. Land Use

28.2 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 4.5 acres (15%) is impervious.

IX. Catchment Name - Laurel Hollow (Low Density Residential)

A. Area - 100 acres.

B. Population - 117 persons.

C. Drainage - This catchment area has a representative slope of 519 feet/mile, 56% served with curbs and gutters and 44% served with swales and ditches. The storm sewers approximate a 275 feet/mile slope and extend 2300 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 3.2 lane/miles of asphalt, 100% of which is in good condition.

E. Land Use

100 acres (100%) is 0.5 to 2 dwelling units per acre urban residential, of which 4.7 acres (4.7%) is impervious.

X. Catchment Name - Centereach

A. Area - 553 acres (But actual drainage area = 3.2 acres - see attached note.)

B. Population - 0 in actual drainage area (see attached note.)

C. Drainage - This catchment area has a representative slope of 53 feet/mile, 100% served with curbs and gutters. The storm sewers (main drainage channel) approximates a 74 feet/mile slope and extend 2400 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 2.2 lane-miles of asphalt, 100% of which is in good condition.

E. Land Use

543 acres (98.2%) is medium-density residential.

10 acres (1.8%) is urban commercial (linear strip commercial development), of which 3.2 acres (0.6%) is impervious.

Note: Centereach Basin

The topographic drainage area surrounding the Centereach Basin is 553 acres, most of which is medium-density residnetial. The actual area draining into the basin, however, is only a portion of the state road (Route 25 - Middle Country Road) that passes through the strip commercial portion of the area. The shopping areas on both sides of the highways have their own individual drainage systems and the residential areas drain into other basins. The basin being tested is a state-owned basin that only drains that portion of the state-owned highway passing through the area (3.2 acres). Thus, some of the data presented in part (X) might appear somewhat confusing.

PROBLEM

A. Local Definition (Government)

The Long Island 208 Study indicated that stormwater runoff is the major source of bacterial loading to the marine waters of the area, and may contribute significant quantities of pollutants to the groundwater reservoir through stormwater recharge basins.

The groundwater reservoir has been designated the "sole-source aquifer" for water supply in Nassau and Suffolk Counties, and the embayments of the area are used for contact recreation, and are the major source of hard-shell clams (*Mercenaria mercenaria*) in the United States.

In most areas of the region, runoff was found to contribute greater than 95 percent of the annual bacterial loading to the bays. Since it is the predominant source of coliform bacteria, stormwater runoff is very likely responsible for much of the shellfish area closures on Long Island, and also threatens many bathing beaches. Surface water quality standards for several bays cannot be consistently attained until the pollutant loading from stormwater runoff is controlled.

Large quantities of pollutants in runoff are known to enter stormwater basins,* which recharge an estimated 10% of all runoff on Long Island. Little is known, however, about the composition and quantity of pollutants that reach the water table after basin storage and exfiltration, or the effect of the soil cover of a basin on the quality of percolate. The 208 study seemed to indicate that urban runoff is a significant source of inorganic chemicals, organic matter and sediment, and may also be a significant source of organic chemcials.

New York State's concern was clearly indicated in its New York State Water Quality Management Plan, which identified urban stormwater management problems. In particular, runoff problems on Long Island were identified as requiring special attention. The State plan recommended additional monitoring, research, and assessment in order to provide a better understanding of nonpoint pollution generation and transport, and a stronger technical basis for identifying and solving runoff problems.

---

* Stormwater recharge basins on Long Island are open pits of various shapes and sizes excavated in moderately to highly permeable sand and gravel deposites of glacial origin. Basins range from 0.1 to 30 acres in area and average 1 acre. Basin depth average 10 feet, but some are deep as 40 feet. More of the water delivered to the basins consists of storm runoff from residential, industrial, and commercial areas and from highways. In 1978, more than 3,000 stormwater basins were in use in Nassau and Suffolk counties.

B. Local Perception (Public Awareness)

The forced closing of shellfish beds and occasional beach closings for health reasons have caused storms of protest at the time the actions were taken. There is contining concern about shellfish bed closures among both commercial and recreational fishermen, and among all citizens who regularly use the embayments for contact recreation - boating, water skiing and swimming - as well, for they rightfully see the shellfish restrictions as a sign of declining water quality which, if allowed to continue, will sooner or later interfere with other uses of the waters. However, these protests tend to be triggered by specific events and ebb and flow with particular crisis in water quality. The relationship of stormwater runoff to these highly visible crisis is complex and requires a technical sophistication only a few random citizens-in-the-street possess. The connection between pollutants in stormwater runoff and contamination via recharge basins of the aquifers which provide drinking water supply is even less visible and more complex technically.

As a result, the problem of controlling pollution from stormwater runoff is not one which has received a lot of independent, self-generated action, or even attention, from the public. However, public participation and education efforts under the original 208 Study were quite effective in alerting both community leaders and interested members of the general publich to the potential dangers of stormwater runoff. Consequently there is growing concern for the need to control stormwater, resulting in a very active publich advisory group for NURP and a high degree of citizen interest in the results.

PROJECT DESCRIPTION

A. Major Objectives

This project comprises sampling programs conducted at nine representative sites to monitor the impact of different land uses upon stormwater runoff loads, and to evaluate the effects of management practices on receiving water quality. Specifically, the project was designed to accomplish the following objectives:

1. Groundwater:
   - to determine the types and quantities of pollutants in runoff entering recharge basins (5 sites) and in percolating runoff entering the groundwater reservoir beneath basins;
   - to evaluate the effects, if any, of the soil cover of recharge basins and basin management practices on the quality of precolating runoff;
2. Surface Waters:
   - to identify the sources, concentrations and loadings for other pollutants in addition to coliform bacteria and nutrients;
   - to determine the practicality and cost-effectiveness of measures proposed for the control and/or treatment of urban runoff;
   - to develop a stormwater management plan incorporating these measures to guide local municipalities.

B. Methodologies

The overall program is being coordinated through the local 208 Agency (LIRPB) as a cooperative effort of the local office of the United States Geological Survey and the staffs of agencies represented on the Technical Advisory Committee (TAC). The TAC is comprised of the Nassau Departments of Health, Publich Works and Planning, and the Suffolk County Water Authority and Department of Health Services.

Nassau County is evaluating control measures at two sites. The runoff generated along Perry Avenue, Bayville was previously uncontrolled and flowed overland, south along Perry Avenue, directly into Mill Neck Creek, contiguous to a bathing beach. The majority of Mill Neck Creek had been closed to shell fishing due primarily to stormwater runoff bacteria loadings. The method of control being evaluated in this drainage basin utilizes an inline storage and leaching system, consisting of a series of perforated catch basins, overflow leaching pools and perforated pipe. Flow measurement data and samples will be collected from three locations: (1) in-flow into a catch basin, (2) in-flow into overflow leaching pool (effluent of catch basin), and (3) over-flow from whole sewerage system into a discharge outfall.

At Unqua Pond, Massapequa, the control measure to be evaluated is settling and sedimentation in a natural impoundment. Samples and flow measurements will be obtained immediately upstream of the pond and at the spillway discharging to the marine waters.

The Suffolk County Department of Health Services is sampling stormwater runoff pollution mitigation measures: (1) street cleaning; (2) energy dissipation at the discharge of a storm sewer to maximize overland runoff and the pollutant removal capabilities of wetlands; and, (3) the pollutant filtering potential of dried up portions of stream beds. Two of the sites are located on Carlls River, which is the freshwater stream with the greatest base flow discharging to western Great South Bay. The third site is located on Orowoc Creek in South Brentwood, Town of Islip. Baseline data has been collected at the Carlls River sites to establish pre-control pollutant levels. Sampling at the Orowoc Creek site will begin in the spring.

The five remaining sites are all recharge basins draining various land uses and will be monitored by the U.S. Geological Survey. At all sites there will be monitoring of the inflow pipe, precipitation and a water-table well to measure water-level changes and the quality of percolating runoff. In one basin there is no existing vegetal cover on the basin floor. In three basins no maintenance is carried out. The fifth basin has an impervious liner and, therefore, contains standing water at all times.

Using the data generated at the nine control sites, the regional effectiveness of the various control schemes will be evaluated by means of the dynamic mathematical models which were developed during the initial 208 study.

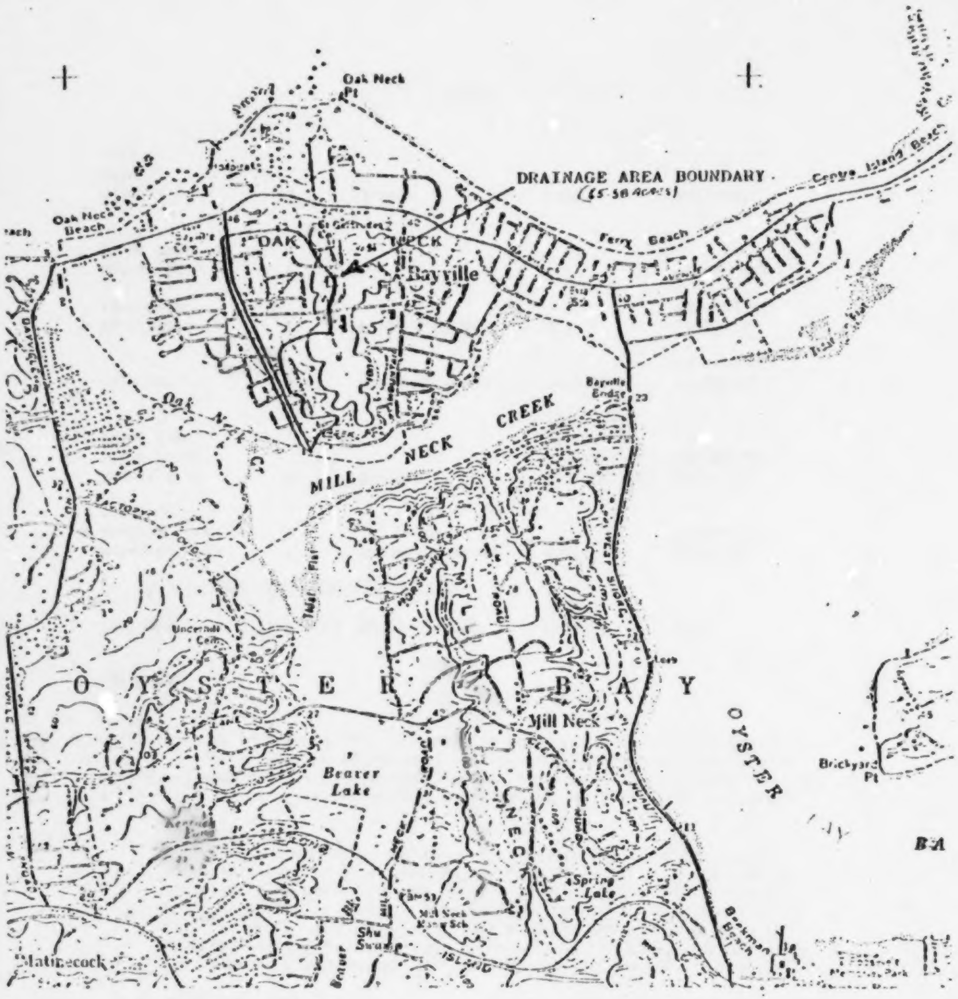
Using information derived from the evaluation phase, and land-use information from the 208 program, suggested stormwater runoff control procedures will be developed for use by local agencies. The procedures will incorporate the most cost-effective structural and non-structural controls for the area. They will be developed as a regional approach to urban runoff control and will have implementation geared to various localities on Long Island and to similar areas of the country elsewhere with specific instructions for management, operation and maintenance of the proposed systems. Requirements for implementation will also be included. The legislative, institutional, fiscal, and administration needs will be addressed.

C. Monitoring

The Bayville site (Figure 3), which is located along Perry Avenue between Bayville Avenue and Creek Road, is in part situated on a steep grade which is topographically representative of the north shore of Long Island. The land use in this drainage basin is essentially all medium density residential, consisting primarily of single family dwellings on 60' x 100' plots, which is typical of development in Nassau County. Automatic sampling and flow measuring devices will be used for sample collection and flow measurement at each of the three sampling points with the equipment located either in the catch basin or overflow leaching pool structures. Bacteriological samples will be collected manually. Precipitation is measured by a recording gauge, installed on the roof of the Bayville Village Hall. Unqua Pond, (Figure 4) is located between Sunrise Highway and Merrick Road, adjacent to Marjorie Post Park. The drainage area contiguous to Unqua Pond is gently sloped and topographically representative of the south shore of Long Island. The land use in this drainage basin is primarily medium density residential, but the pond also receives runoff from Sunrise Highway, which is a major east-west thoroughfare, from a commercial shopping center and from the adjacent park land. Most of the stormwater discharge in this basin is diverted into Unqua Pond and subsequently into South Oyster Bay. Portions of South Oyster Bay adjacent to the shoreline are presently closed to shellfishing, primarily due to the bacteria loadings from stormwater runoff. Although there are a number of ponds located along the south shore of Nassau County, Unqua was selected for three reasons: (1) relatively deep (3 to 5 ft) as compared to most ponds, which are shallow (1 to 3 ft), (2) only one direct discharge into the pond in addition to the primary stream inflow, (3) easy accessibility to the inflow and outflow sampling locations. Essentially all sampling will be conducted manually since the pond system is unsecured and subject to vandalism. Automatic samplers may be used once on site, but bacteriological samples must be collected manually. Precipitation is measured by a recording gauge set up on the roof of the Marjorie Post Park Administration building, located at the southern end of the drainage area.

Suffolk County Department of Health Services is studying three surface water sites, as follows: Two sites are located on the Carlls River and are being used to test the effectiveness of street sweeping. The sweeping is being conducted at site (1) Central Avenue, which has a drainage area of approximately 73 acres medium-density residential land use. Streamflow gauging and water quality sampling are carried out at a location in the stream channel downstream of the discharge points of the two 48" diameter and one 24" diameter storm sewers.

Site (2), located on the west branch of the Carlls River, and a few thousand feet north of Belmont Lake, will be used as a control on the street sweeping evaluation at Central Avenue. The site has a 48" diameter storm sewer collecting runoff from a drainage area of approximately 64 acres of medium density residential land use along Westview Avenue and West 24th Street. Flow measurement and water quality sampling are done at the pipe discharge, and in the stream channel upstream and downstream from the pipe. Precipitation is measured by a recording gage located at Belmont Park Headquarters and by manual gages set up at the sites by sampling crews.



IN-LINE STORAGE SYSTEM
PERRY AVE. BAYVILLE

Reproduced from best available copy.

Site (3) is at a trapezoidal shaped recharge basin just to the north of the Southern State Parkway in South Brentwood, Islip town, located on the service road to the parkway. The basin is approximately 450' long and 300' wide at its longest and widest points. There is a storm drain draining a small residential area that discharges into the east side of the basin, roughly 200' downstream from the stream influent point at the northern end of the basin. A low (8"-10" high) concrete wall at the end of the 10' long concrete apron to the storm drain, which has been in place for at least 15 years, acts as a working, effective energy dissipator. The basin and stream channel upstream are heavily overgrown with wetlands vegetation and, hence, provide an effective site for wetlands treatment. Upstream of the recharge basin, the channel is dry for much of the year and resembles the conditions predicted in the Suffolk County Flow Augmentation Needs Study (FANS) for streams without augmentation.

The parameters analyzed in samples from the above sites include: TKN, NH_3-N, NO_2-N, TOC, COD, TSS, Chloride, BOD, Total Coliforms, Fecal Coliforms, Fecal Strep, lead, chromium, cadimium, zinc, copper, iron, and mangenese.

The five recharge basins being monitored by U.S.G.S. are as follows: (Sample site shown in Figure 6):

- Laurel Hollow is located at the intersection of Cove Road and Moore's Hill Road in Laurel Hollow, N.Y.. This basin drains a 100-acre area of recently-constructed, medium-density housing. Some construction was still going on in 1979. The basin is three acres in area and trapezoidal in shape. The basin floor is approximately 14 feet below land surface.
- The Plain view basin, also known as New York State Department of Transportation Highway Basin 66, is located at the intersection of Washington Avenue and Executive Drive in Plainview, N.Y. This basin receives runoff from the Long Island Expressway, its service road, and a small number of local streets - a total of 7,000 feet of roads, or approximately eight acres of impervious surface area. The basin is approximately two acres in size and square in shape. The basin floor is 40 feet below land surface.
- The Syosset stormwater recharge basin is located at Cary Street in Syosset, N.Y. This basin is also known as Nassau County Storm Water Basin 377. This basin drains a 28.2-acre high-density residential area. Housing construction in this area was completed in 1957. The basin itself is one acre in size and triangular in shape; its bottom is 14 feet below land surface.
- The Huntington stormwater recharge basin is located at Walt Whitman Shopping Center on Route 110 at South Huntington, N.Y. This basin

drains the north half of the shopping center which includes approximately 39 acres of paved parking and roof area. This basin is clogged, but storm water can exfiltrate the walls above the clogging layer. The number of shopping center basins is small (less than 50), but the large volume of man-made organic compounds that enter these basins may have a disproportionately large impact on the quality of ground water.

The Centereach stormwater recharge basin is located near the northwest corner of the intersection of Oak Street and Middle Country Road (N.Y. Route 25) in Centereach. This basin drains Middle Country Road and the commercial areas on both sides of the road. This basin is different from the other four in that it has a liner, which causes it to retain a pre-determined volume of water. Excess stormwater is recharged to the ground water via an overflow pipe connected to a leaching field.

In all five basins, flow measurement data, water-quality samples and microbiological samples will be collected at the inflow pipes. A watertable well will be placed in each basin to monitor water-level changes and the quality of percolating runoff. A rain gage will be placed in each basin to record rainfall input.

Equipment

Equipment	# of Pieces	Manufacturer	Model #	Site
I. NASSAU COUNTY DEPARTMENT OF HEALTH				
Automatic Recording Rain Gauge	2	Weather Measure	P501-I	Bayville, Massapequa
Manual Rain Guage (dipstick type)	2	Belfort	U.S. Weather Bureau Specification #4502301	Bayville, Massapequa
Flow Meter	3	Marsh-McBirney	VMFM 265	Bayville, Massapequa
Portable Flow Meter	1	Marsh-McBirney	201	Bayville, Massapequa
Manual Flow Gauge-Staff Gauges	2	--	--	Massapequa
Automatic Water Sampler	3	ISCO	2100	Bayville, Massapequa
II. SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES				
Flow Meter	3	Marsh-McBirney	VMFS 265	Carlls River-Energy Dissipation
Conductivity Meter	1	Horizon Ecology Company	1484-10	Sampling Vehicle
Cone Sample Splitter	1	Leonard Mold & Die	-	Sampling Vehicle
pH Meter	1	Horizon Ecology Company	5995	Sampling Vehicle
or				
pH Meter	1	Leeds & Northrup	7417-L2	Sampling Vehicle
D. O. Meter Temperature	1	Yellow Springs Instruments	57	Carlls River-Energy Dissipation
Standard 8" Diameter Manual Rain Gage*	1	Science Associates		Level area at Sampling site
Tipping Bucket Rain Gage*	1	Weather Measure Corporation		Belmont Lake State Park Headquarters
III. U. S. GEOLOGICAL SURVEY				
Automatic Sampler	4	Manning	S-6000	Five basins, four instrumented at any given time
Velocity Modified Flow Meter	5	March-McBirney	250	Five basins, four instrumented at any given time
Minigraph Event Recorder	4	Esterline Angus	none	Five basins, four instrumented at any given time
Tipping Bucket Rain Gage w/Recorder	4	Leupold & Stevens	7012	On-site at Huntington Laurel Hollow, Plainview Syosset - rear of USGS off.
Atmospheric Deposition	2	N-Con	none	Huntington Basin Plainview Health Center
Water-Level Recorder	4	Leupold & Stevens	Type F	Five basins, four instrumented at any given time

Controls

The in-line storage system in Bayville, New York, consists of a series of leaching-type catch basins and leaching pools connected with perforated reinforced concrete pipe. The catch basins are located strategically along Perry Avenue for collection of runoff from storm event. Any overflow from the basins enter perforated pipes (where some leaching also occurs) that allow the stormwater to flow from one leaching pool to the next as each fills. If the storm runoff is of sufficient volume to fill all the leaching catch basins and pools, then the excess volume will flow into Mill Neck Creek. Figure 7 shows cross sectional views of a typical leaching pool, leaching-type catch basin, and perforated pipe. The design capacity of this stream will theoretically retain a one-in./24-hour storm before there is any overflow and discharge to the marine waters. This design is intended to capture and retain the stormwater generated from approximately 85% of the rainfall events in the Long Island area.

Unqua Pond is located in the Village of Massapequa between Sunrise Highway and Merrick Road adjacent to Marjorie Post Park. The pond is relatively deep (3 to 5 ft) compared to most ponds on Long Island, which are shallow (1 to 3 ft) Unqua Pond has one stream influent and effluent, but it also receives urban runoff from a small stormwater drainage system discharge. Natural sedimentation on detention are the processes that are being evaluated by this control measure. The site is currently a control measure as it exists, and the only changes that will occur are the installation of monitoring equipment. Ducks and geese located on and around the pond contribute significant quantities of nutrients, biochemical oxygen demand, and bacteria to the pond. Feeding of the ducks and geese by people in the area tends to increase their population around the pond, thus contributing to more pollution.

For the Carlls River street cleaning site, existing Elgin Pelican street cleaning equipment will be used. This equipment will be operated in accordance with a predetermined operation schedule. At present, this area has a typical street cleaning frequency of five times per year. During the NURP study, the same mode of operation and piece of equipment should be used to control the number of variables to be considered when evaluating the results of street cleaning. Frequency of sweeping and antecedent rain will be the only major variables.

The dry stream channel energy dissipation/wetlands treatment at Orowoc Creek involves a recharge basin through which the stream channel passes. Up stream of the recharge basin, the channel is dry for much of the year, which would resemble the conditions predicted in the Suffolk County Flow Augmentation Needs Study for several of the streams without augmentation. In addition, there is a storm drain which discharges into the basin from a small residential area. The stream channel and the recharge basin are heavily overgrown, the latter with typical wetlands species.

Suffolk County Department of Health Services will be assessing the stormwater runoff treatment benefits that may result from the drying up of portions of streams due to the effect of sewering. The department is in the process of establishing a monitoring station at the basin influent to evaluate the treatment provided by the dry stream channel; a monitoring station at the storm drain discharge to the basin, to sample runoff from the small residential area; and a sampling point at the basin effluent to evaluate the treatment provided by the wetlands vegetation and from recharge in the basin.

Because of the existence of heavy vegetation in the channel up stream and also in the recharge basin, it is anticipated that there will be several storms for which there may not be measurable flow at the basin's influent or effluent points.

The originally proposed energy dissipation construction at the Westview Avenue site, on the Carll's River, has been dropped from the study for the following reasons:

> the low bid for constructing the facility was $41,000, which was approximately $20,000 more than the consultant's estimate.
>
> although the SCDHS' field crew had identified 40 to 50 potential sites where energy dissipation could be implemented, the total contributory drainage area to these sites has been found to be less significant than envisioned prior to the site inspections.
>
> energy dissipation/wetlands treatment will be better evaluated at the storm drain discharge to the Orowoc Creek Site, where an existing energy dissipator and wetland has been operating for many years.

The Westview Avenue site is being retained in the monitoring program to facilitate evaluation of the impact of varying street cleaning practices at Central Avenue. Both Carll's River sites will be sampled during the same storm events.

Reproduced from
best available copy.

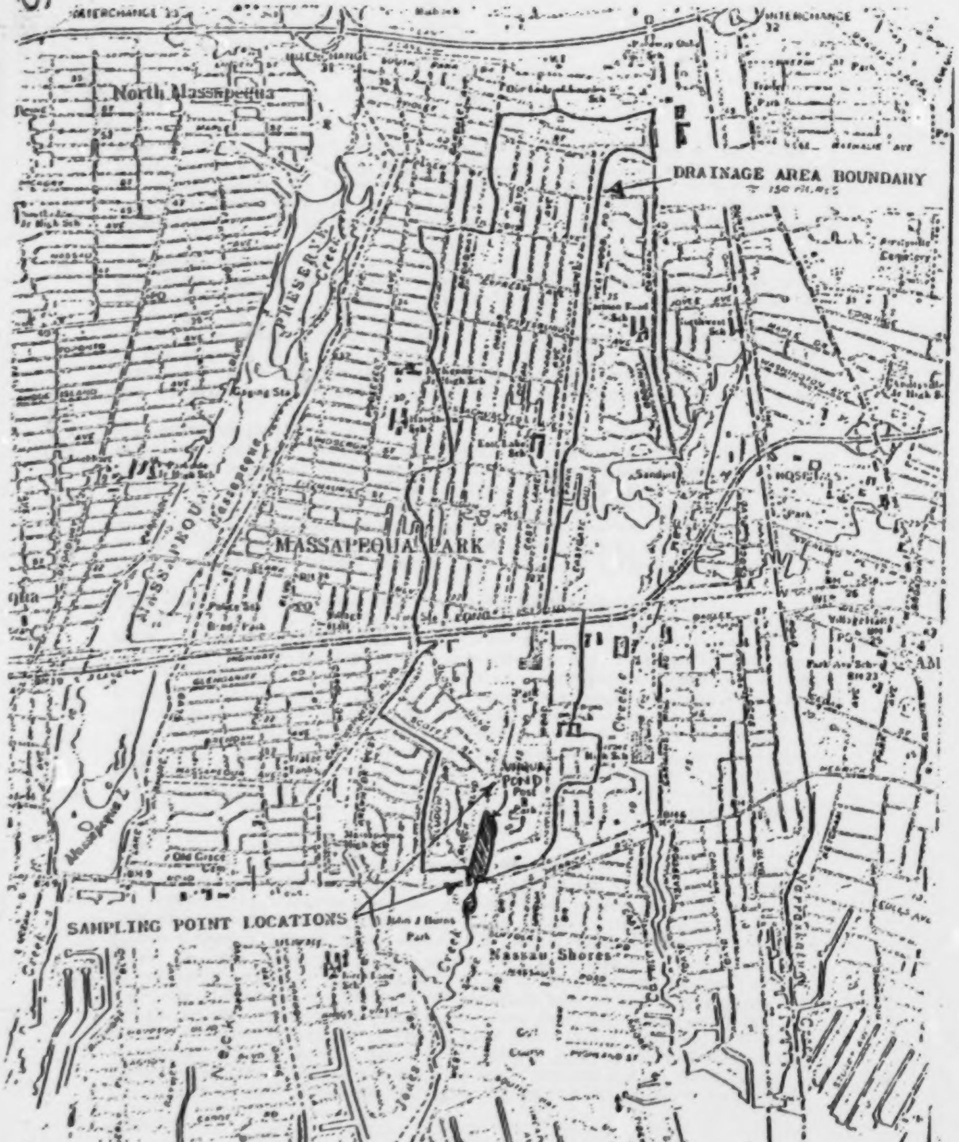


Figure 3
PLAIN SEDIMENTATION-NATURAL IMPOUNDMENT SYSTEM
UNQUA POND MASSAPEQUA G4-22

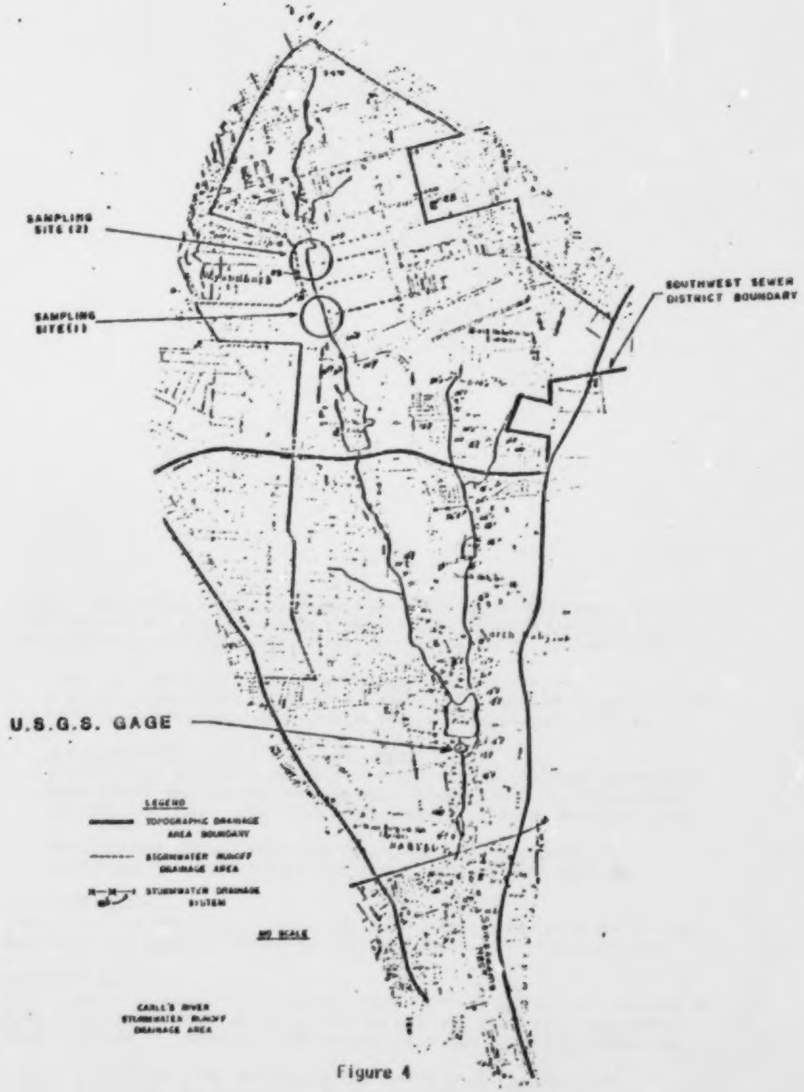

SAMPLING SITE (2)
SAMPLING SITE (1)
SOUTHWEST SEWER DISTRICT BOUNDARY
U.S.G.S. GAGE
LEGEND
TOPOGRAPHIC DRAINAGE AREA BOUNDARY
STORMWATER RUNOFF DRAINAGE AREA
STORMWATER DRAINAGE SYSTEM
NO SCALE
CARLL'S RIVER STORMWATER RUNOFF DRAINAGE AREA

Figure 4

NOTE: The following section is excerpted from the Long Island Regional Planning Board's 208 Comprehensive Waste Treatment Management Plan, published in 1978!

2.2 GROUND WATER POLLUTION SOURCES

2.2.1 Background

An evaluation of ground water pollution sources is one of the products of the Long Island 208 areawide waste management study. A full report, presented to the 208 Technical Advisory Committee by Geraghty & Miller, Inc. in September 1977, describes eighteen different activities which have or may impair ground water quality in the study area. This section has been prepared to provide easy access to the salient facts contained in the longer, more technical version. The potential impact of the various contamination sources discussed may be subject to reassessment at a later date as more data are made available, or as legal requirements initiate a change in practices.

Although the ground water contamination contribution of several of the sources described may not appear to be significant, it should be borne in mind that the quality of the regional ground water supply is susceptible to the adverse effects of the sum total of man's activities on land. This understanding is particularly crucial to Long Island where activities are diverse, and where a water supply alternative to ground water is not readily or economically available.

There are many sources and causes of ground water contamination in the 208 area. Basically, they can be divided into four categories (Table 2–1). The first two categories represent discharges of contaminants that are derived from solid and liquid wastes. The third category concerns discharges of contaminants that are not wastes, and the fourth category lists those causes of ground water contamination that are not discharges at all.

The variety and type of management options available for each category differ. For example, some Category I sources may require a discharge permit whereas others can be controlled by restrictions on land use. Sources under Category II may require satisfaction of specified construction standards, such as the lining of landfills and the installation of leachate collection systems. Guidelines and manuals (*e.g.,* tons/land-mile limits on highway deicing salts) may be the only type of management option available for Category III. Special regulatory controls are available for the causes of ground water contamination listed under Category IV. An example is the current system of ground water diversion applications and hearings employed to minimize salt water encroachment. Another is the licensing of drilling contractors in order to upgrade water well construction practices.

2.2.2 Domestic On-Site Waste Disposal Systems

Cesspools, septic tanks and leaching fields are a source of ground water contamination on Long Island that has been of great concern to many investigators and regulatory agencies. "The Final Report of the Long Island Ground Water Pollution Study" stated that 800,000 persons in Nassau and 950,000 persons in Suffolk reside in unsewered areas (Nassau-Suffolk Research Task Group, 1969). In addition, facilities serving 24,000 people residing in Nassau Sewer District No. 2 were reported as not being hooked up to the sewer system. Other reports give different estimates for the number of cesspools and septic tanks in Nassau County (Nassau Environmental Management Council, 1974 and Padar, 1968). The U. S. Geological Survey has estimated that in 1966, 120 million gallons per day of sewage were returned to the ground through cesspools and septic tanks on Long Island (Parker, 1967). A more recent paper from the Nassau County Department of Health reports that 150,000 cesspools in Nassau alone discharge 60 million gallons per day (Smith, 1975).

In on-site disposal systems, bacterial action digests the solid materials, and the liquid effluent is discharged to the ground. In theory, filtration by earth materials provides additional treatment so that the liquid, when it arrives at the water table, is relatively clean. However, many constituents carried by the effluent are introduced to the ground water system. Those which present the greatest threat to ground water quality are excessive concentrations of nitrate, organic chemicals, detergent, metals, bacteria and viruses. Other constituents–previously ignored, but now recognized as a

Table 2–1

CLASSIFICATION OF SOURCES AND CAUSES OF GROUND WATER CONTAMINATION USED IN DETERMINING LEVEL AND TYPE OF CONTROL

Category I **Systems, facilities or sources designed to discharge waste or waste waters to the land and ground waters.**	**Category II** **Systems, facilities, or sources not specifically designed to discharge wastes or waste waters to the land and ground waters.**	**Category III** **Systems, facilities, or sources which may discharge or cause a discharge of contaminants that are not wastes to the land and ground waters.**	**Category IV** **Causes of ground water contamination which are not discharges.**
Domestic on-site waste disposal systems	Sanitary sewers	Highway deicing and salt storage	Airborne pollution
Sewage treatment plant effluent	Landfills	Fertilizers and pesticides	Water well construction and abandonment
Industrial waste discharges	Animal wastes	Product storage tanks and pipelines	Salt water intrusion
Storm water basin recharge	Cemeteries	Spills and incidental discharges	
Incinerator quench water		Sand and gravel mining	
Diffusion wells			
Scavenger waste disposal			

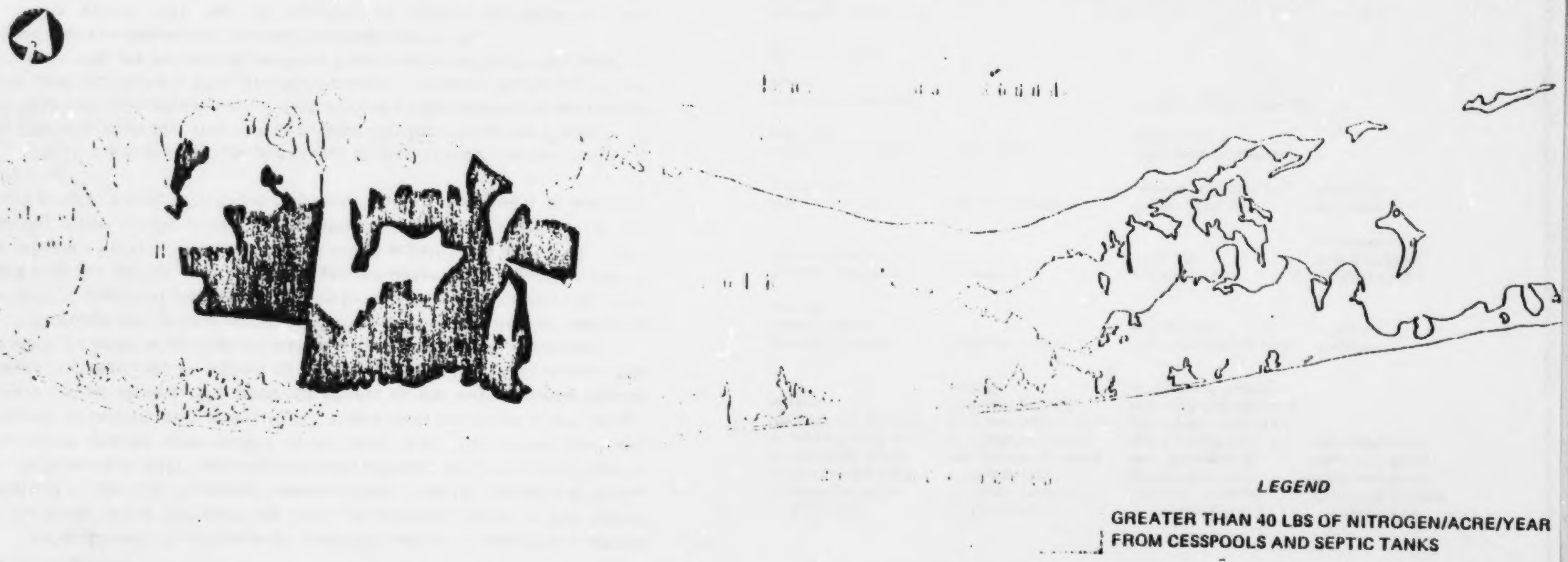
threat—are halogenated hydrocarbons. Compounds such as chloroform, carbon tetrachloride, trichloroethylene, and others are in common use in industry as degreasers and solvents or are incorporated in plastic products. It has only recently been recognized that these and similar compounds regularly occur in discharges from households. Many products common in the home, such as fabric and rug cleaners, workshop cleaners and solvents, and solutions to clean pipes find their way into on-site disposal systems. Septic tank cleaners are composed almost entirely of active ingredients which are frequently halogenated hydrocarbons. For example, one common cesspool cleaner contains more than 99 percent trichloroethylene. One gallon of this compound could raise the trichloroethylene concentrations of 29 million gallons of water to the State recommended maximum of 0.05 parts per million.

Cesspools and septic tanks are viewed by regulatory agencies as low-cost systems which eliminate surface discharges of raw sewage. There are areas where low housing density and favorable soil conditions make such systems satisfactory alternatives to expensive trunk sewers and treatment plants. However, government agencies have been leaning more and more toward the latter in recent years. Sewer districts have been delineated in both counties and plans for construction are well underway. Figure 2–14 is a nitrogen-loading map, showing the areas in which more than 40 pounds of nitrogen are added annually to each acre by cesspools and septic tanks (Weston, July 1976). This map does not include the nitrogen loading that results from agricultural and domestic fertilizer applications.

2.2.3 Sewage Treatment Plant Effluent

At present, sewage treatment plant effluent is only a minor threat to ground water quality in the bi-county area, as most of the effluent is discharged directly to the sea. According to a study made by Weston in 1976, 23 plants in Nassau County discharge an average of 105.63 million gallons per day, and in Suffolk County 101 plants have an average discharge of 14.26 million gallons per day (Weston, July 1976). These are the total flows of the NPDES and SPDES permitted sewage treatment systems and are believed to include all plants in both counties. Figure 2–15 shows the locations of plants that discharge to the ground.

In Nassau County, only one percent of the total daily flow of treated



LEGEND

GREATER THAN 40 LBS OF NITROGEN/ACRE/YEAR FROM CESSPOOLS AND SEPTIC TANKS

FIGURE 2–14 *Areas of Major Concentrations of On-Site Domestic Waste Disposal Systems.*

effluent (1.2 million gallons per day) and in Suffolk County 50 percent of the total daily flow of treated effluent (7.39 million gallons per day) are discharged to the ground. Thus, a total of 8.59 million gallons per day enters the ground compared to about 800 million gallons per day total recharge of fresh water from precipitation in the bi-county area. Although small, this discharge of effluent to the ground may have a significant effect when concentrated at a few sites. In Nassau County, effluent is discharged at five sites: Meadowbrook Hospital (0.77 million gallons per day), Farmingdale Sanitorium (0.07 million gallons per day), C. W. Post College (0.12 million gallons per day), New York Institute of Technology (0.003 million gallons per day), and Grumman Aerospace Corp. (0.25 million gallons per day).

In Suffolk County, the 85 facilities which discharge treated sewage effluent to the ground are predominantly small residential facilities and some special health and elderly care facilities (Weston, July 1976). Suffolk County is undergoing rapid development and many small sewage treatment plants are being installed to serve areas of 100 or more homes. In developments of less than 100 homes where no sewer system is available, builders are required to install sewers, which will be placed into service after future construction of a nearby interceptor. These homes are permitted to temporarily discharge to cesspools and septic tanks (Pim, 1977).

Some systems receive domestic wastes exclusively; others accept some industrial wastes. Regulatory authorities make every effort to exclude constituents harmful to the treatment plant process or employees, but incidental discharges are not easily controlled. Some chemicals, such as solvents, do not appear to be harmful over the short term, but may damage either the plant or sewer system over a long period of time.

According to a NYSDEC law, effective secondary treatment is the minimum required before effluent can be discharged to surface water. Although this law does not apply to plants discharging to the ground, secondary treatment also is common. Only Farmingdale Sanitorium in Nassau discharges primary treated effluent to the ground (0.07 million gallons per day). In Suffolk, of the 85 plants discharging to the ground, only six do not provide at least secondary treatment. Denitrification of sewage effluent is now required of all new sewage treatment plants which discharge to ground water in Suffolk County.

A recently released report by Roy Gilbert of the SCDEC states that

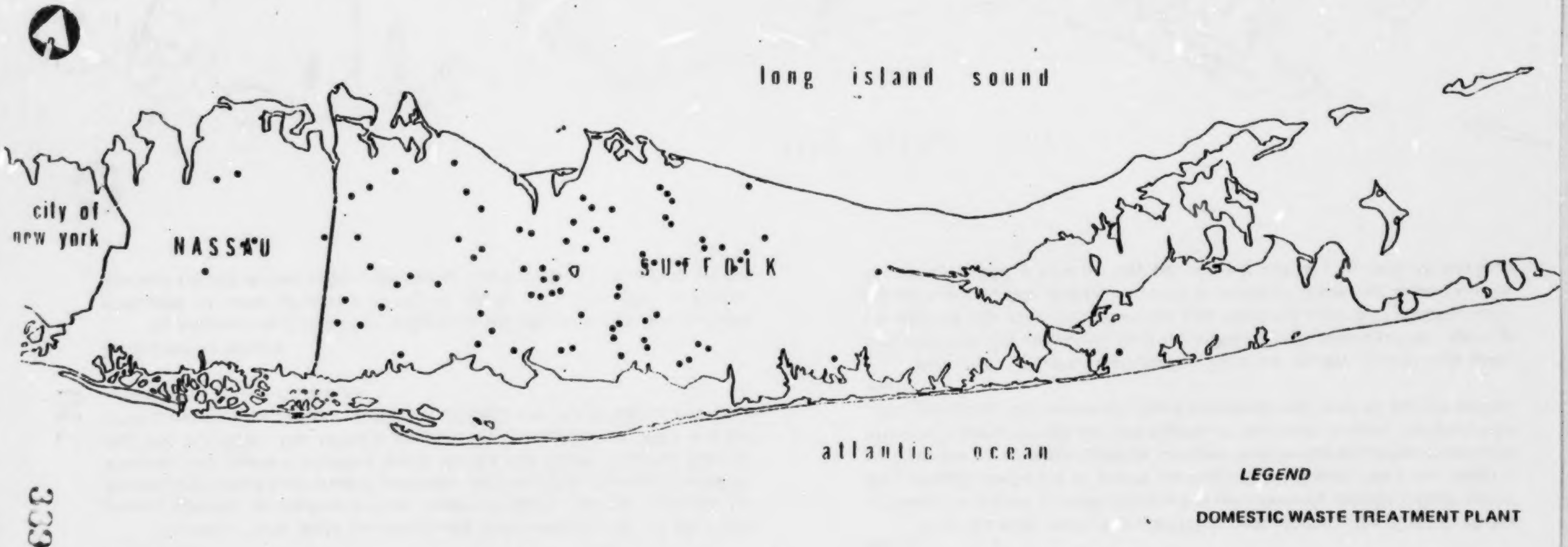


FIGURE 2–15 *Domestic Waste Treatment Plants Discharging to Ground Water,* 1978

a number of organic compounds present in treated sewage are refractory products (not affected by the treatment process) of the biological treatment of the plant, or new compounds formed during chlorination (Gilbert, 1977). It is possible that these products may move through the unsaturated soil to contaminate ground water in places where the effluent is discharged to the ground.

The New York State Environmental Conservation Law of 1967 empowers agencies to regulate sewage treatment plants. This law provides for the classification of state ground water and establishment of quality standards. Violators are assessed penalties under the Federal Water Pollution Control Act (PL 92–500). The NPDES program was established in 1973 and the SPDES program in January 1975; the SCDEC and the NCDH derive their enforcement powers from these.

2.2.4 Sanitary Sewers

Approximately 120 million gallons per day of raw sewage flow through thousands of miles of sewers in the bi-county area. The flow in Nassau averages 105.63 million gallons per day and in Suffolk, 14.26 million gallons per day (Weston, July 1976). Figure 2–16 shows the locations of sewered areas. Sewers frequently leak, and depending upon the type of sewer and its altitude relative to the water table, ground water can infiltrate or sewage can exfiltrate. The contamination that takes place in the latter case is normal domestic sewage, plus those constituents in industrial effluent discharged to sewers.

Since the enactment of the SPDES permit program, the direct discharge of industrial wastes to septic systems has been severely curtailed. Restrictions on industrial discharges to sewers are much less stringent than those covering such discharges to septic systems. Concern over the constituents in industrial effluent is primarily due to their effects on the sewer system, the treatment plant processes, and treatment plant personnel—not their effects on ground water.

Permissible maximum infiltration rates are usually written into sewer specifications and commonly vary from 200 to 500 gallons per day per mile per inch of pipe diameter. Where ground water pollution is of concern, exfiltration rates are also specified. In Suffolk County's Southwest Sewer District, for example, 200 gallons per day per mile per inch of pipe diameter has been

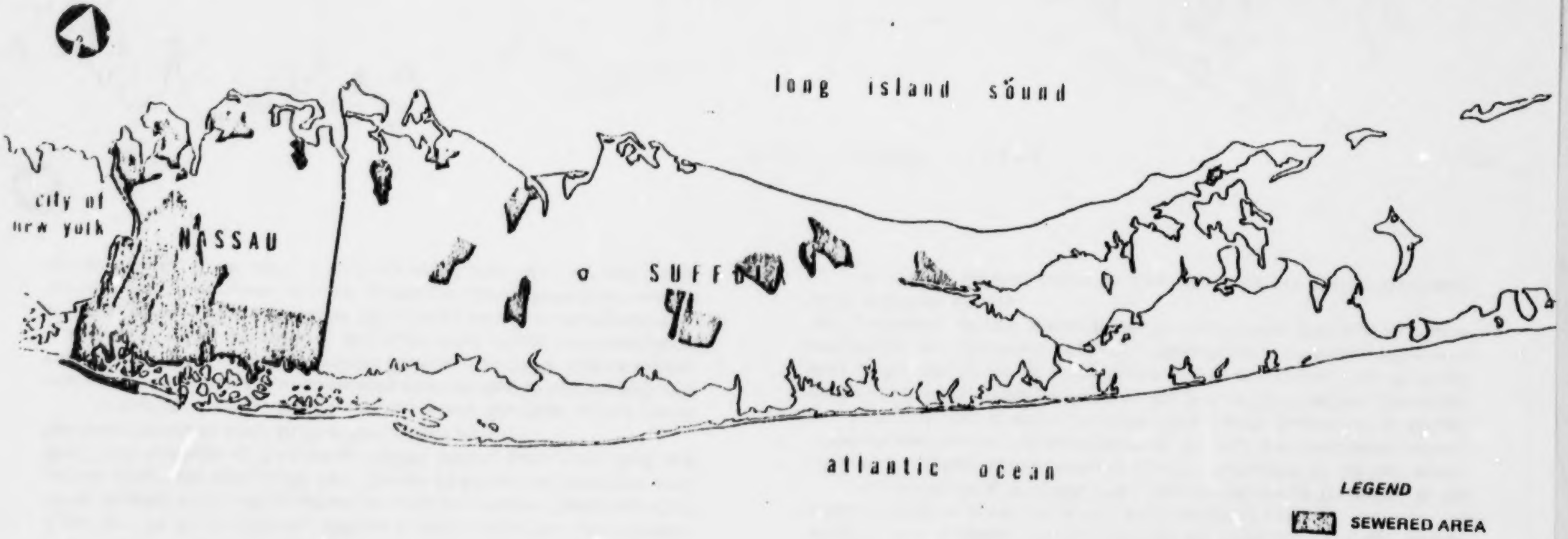


FIGURE 2–16 *Presently Sewered Areas,* 1978

specified as the maximum rate for exfiltration. Projections from tests carried out on existing sewer lines show that leakage has been considerably less than this figure (Graner, 1977).

The potential volume of exfiltration is small when compared to the nearly 100 percent discharge that occurs from cesspools and septic tanks. However, exfiltration may increase over the years as loading produces breaks in the pipes and joints, and as chemical action deteriorates the joints. Exfiltration may also increase if the ground water level was originally above the sewer, but has declined to a point below the sewer.

With present materials and construction techniques, a 50 year sewer life is used as a minimum design estimate. However, a 100 year life may be a more reasonable estimate (Graner, 1977). Some of the older systems in Nassau County are receiving large volumes of ground water (Long Beach, Glen Cove, Oyster Bay and Freeport) (Cameron, 1977). If these systems are infiltrating additional water where the pipes are below the water table, it is reasonable to assume they are also exfiltrating additional sewage where the pipes are above the water table. Similar problems may be occurring in older Suffolk systems, such as Port Jefferson, Huntington, Northport and Patchogue.

Except for monitoring volumes, and to some extent, chemical quality of incoming waste at sewage treatment plants, little control is exerted on sewers once the construction specifications are satisfied. Severe problems involving exfiltration, infiltration or clogging are remedied where they interfere with the operation of the system or cause a public nuisance.

2.2.5 Industrial Waste Discharge

Industrial development and zoning are extensive on Long Island. In 1972, five percent of the Nassau-Suffolk area was zoned for industry. Most of this acreage is inland and includes such heavily industrialized areas as Syosset, Hicksville, Bethpage-Plainview, Melville-Farmingdale, Hauppauge and Deer Park. Except for a small part of the Melville-Farmingdale area, all of these zones and a number of smaller ones in Suffolk County are located in the recharge area of the Magothy aquifer. Areas of known industrial discharge to the ground are shown on Figure 2–17.

Although there are discrepancies in the number of industries reported to have permitted discharges, the nature and volume of NPDES and SPDES discharges are documented in a 1976 report prepared by Roy F. Weston

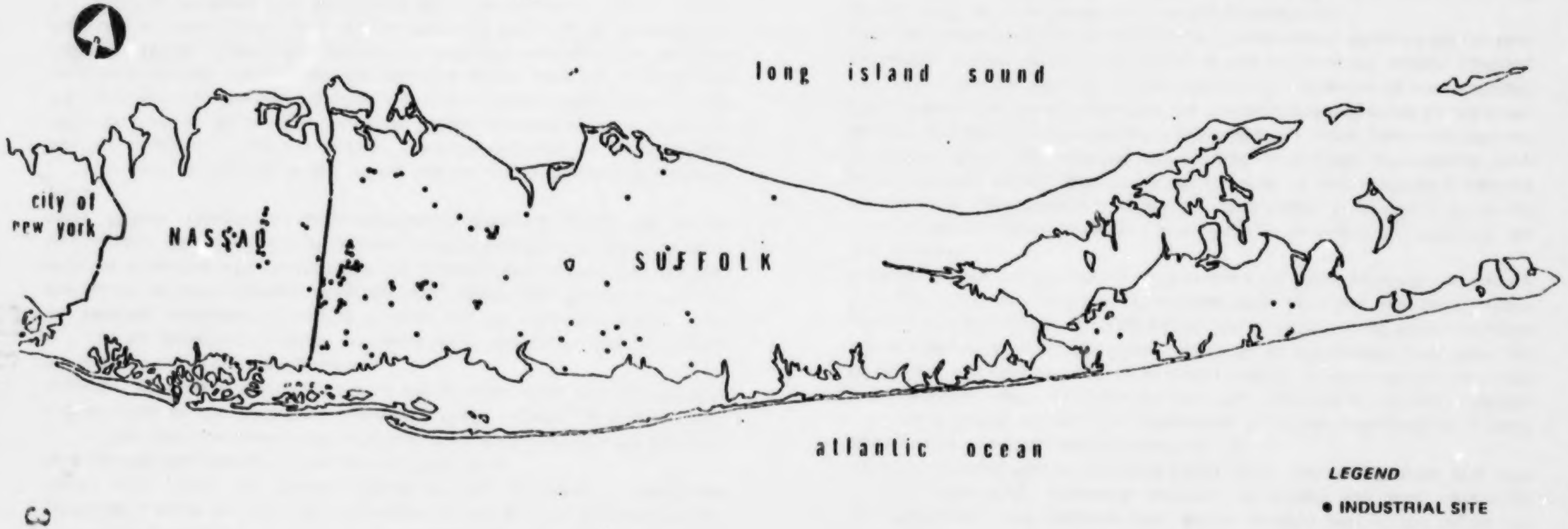


FIGURE 2–17 *Major Industrial Sites Discharging to Ground Water,* 1978

(Weston, July 1976). According to the report, in Nassau 1.2 million gallons per day of waste water are discharged by industry. About 800,000 gallons per day of this amount are discharged to the ground. In Suffolk County, 88 industries discharge a total of 1,325,000 gallons per day, of which 1,278,900 gallons per day are discharged to the ground. Thus, in the bi-county area, about 2.1 million gallons per day of industrial wastes are discharged to the ground in a few industrialized areas.

There are also commercial and industrial discharges in both counties, not included in the permitted inventory. These include car washes, coin-operated laundries and industries discharging waste water with constituents not covered by permitting regulations.

In an attempt to control industrial waste discharges, Nassau County has recently instituted a program to inventory all industries, according to the nature of and receiving body for their discharges. The inventory has revealed a number of industries that are discharging untreated liquid wastes to cesspools (Burger, 1977). Abatement actions have been initiated in these cases. Suffolk County has been conducting industrial surveys for several years.

In Suffolk County, a list of car washes and coin-operated laundries has been compiled. Ten car washes presently discharge to ground water; these predate the State DEC regulation requiring closed systems. There are 135 coin-operated laundries discharging to the ground water; two of these have once-through waste treatment and four others have partial treatment (Gilbert, 1977). Twenty-five percent of Suffolk's coin-operated laundries discharge to sewers and require no pre-treatment (Pim, 1972). Forty-five of the laundries discharging to the ground are in the Southwest Sewer District and will be sewered in the future. Nearly 500,000 gallons per day discharges to ground water from 75 of these laundries.

In Nassau County, permitted discharges to the ground amount to about 800,000 gallons per day. Fourteen metal processing firms discharge 726,000 gallons per day, which is 90 percent of the total. The bottling industry produces an additional 32,000 gallons per day, and the food industry, 24,000 gallons per day. Very small discharges are from metal powder mixing and paper processing industries (Weston, July 1977).

In Suffolk County, 1,278,900 gallons per day of industrial wastes are discharged to the ground. This includes 470,989 gallons per day from metal processing, 356,813 gallons per day from commercial laundries, 164,978 gallons per day from dairies and 152,189 gallons per day from bakeries.

Prior to the passage of the New York State Environmental Conservation Law in 1967, there was no effective law limiting the types of waste water discharged to the land surface. With the enactment of the NPDES and subsequent enactment of the SPDES, a NYSDEC permit is required for non-sewered industrial effluent discharges. The industry must produce treated effluent which meets state water standards. Compliance is monitored by the NCDH and the SCDEC. These agencies also enforce sludge disposal rules.

2.2.6 Storm Water Basins

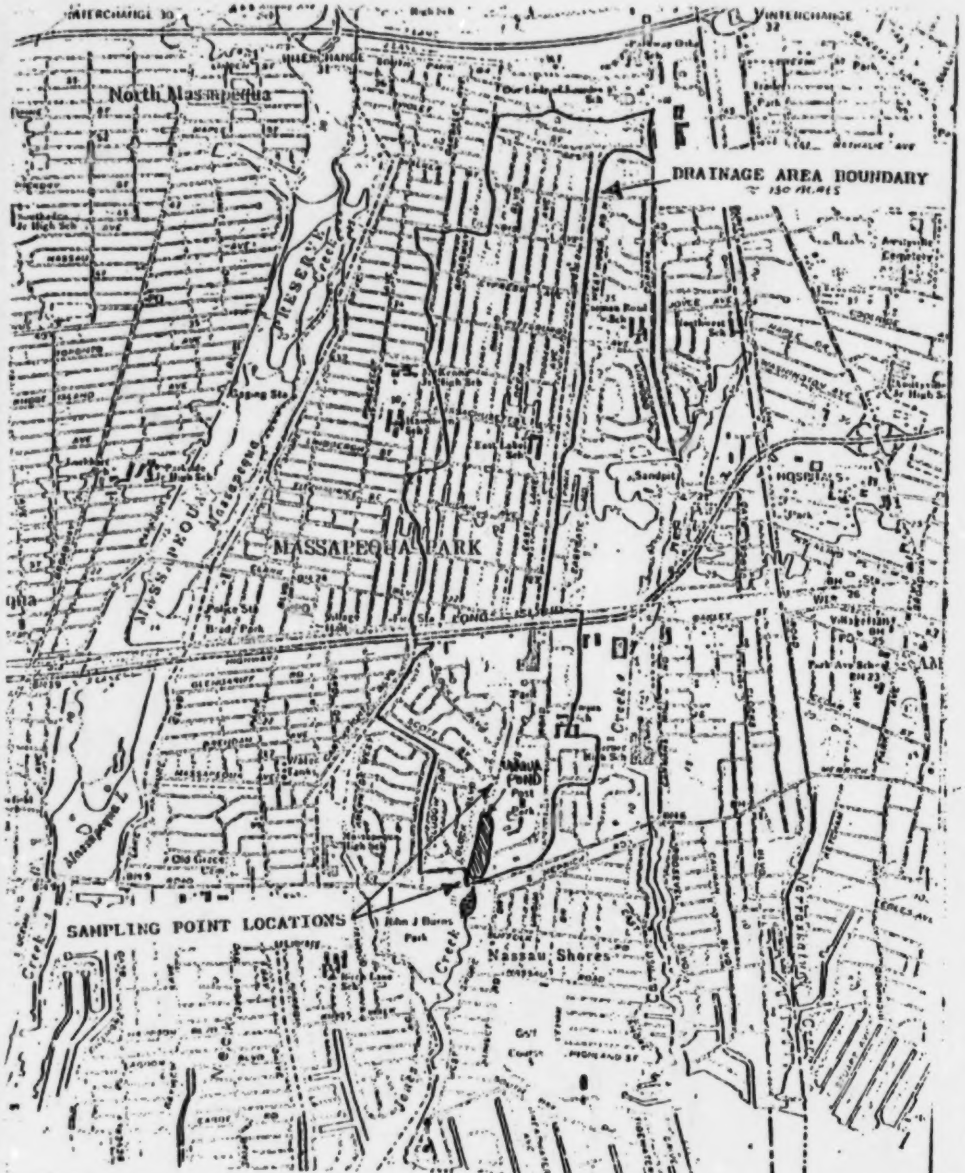
Investigators have determined that on Long Island approximately half the annual precipitation finds its way to the ground water reservoir as recharge. This averages roughly one million gallons per day per square mile in a 760 square mile recharge area. As the western part of the region has become increasingly urbanized, however, permeable soil areas have been replaced by impermeable roofs and paved areas. The water cannot seep into these surfaces, so it accumulates and runs off.

As a water conservation alternative to offset reductions in ground water recharge and to eliminate the need for expensive trunk sewers leading to the sea, a system of small storm sewers draining to unlined recharge basins was implemented in Nassau County in 1935. At the present time, there are more than 2,000 basins on Long Island, the locations of which are shown on Figure 2–18 (Seaburn, 1973). The basins range from less than one to more than 30 acres in size but most are about one acre. They average ten to twenty feet in depth.

Recharge basins have been considered to be highly beneficial to the overall water conservation program on Long Island, since they account for approximately twenty percent of all recharge to the underlying aquifers (Aronson, 1974). Although the basins restore potentially lost recharge, they are also sources of contamination. Inflow into the basins is a combination of precipitation plus constituents that are dissolved and suspended by the water as it runs over the ground. Typical sources of contaminants are fertilizers, pesticides, deicing salts, organic debris, grease and road oil, rubber, asphaltic materials, hydrocarbons, animal feces and food wastes. Many of the contaminants are not biodegradable and persist in ground water.

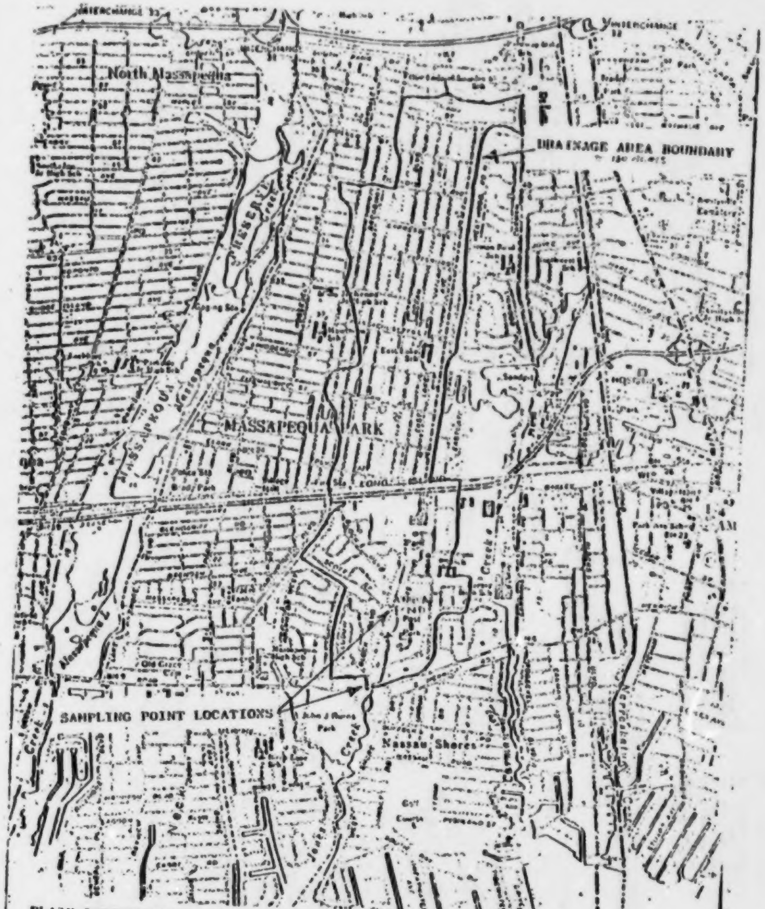
As part of the 208 investigation, a number of studies were conducted which have bearing on the amount and types of pollutants that may be entering the ground water system via storm water basins. The Weston non-point source analysis included sampling runoff from small drainage areas and correlation of the runoff quantity and quality with the prevailing land uses. The data and analyses indicated that annual loads of pollutants from non-point sources can be as large as loadings from traditional point sources (Weston, April 1977).

In their program of storm water runoff and ground water sampling at two recharge basins along the Long Island Expressway, the SCDEC detected significant intermittent concentrations of selected heavy metals (*e.g.*, zinc and lead) and total organic carbon (TOC) in discrete samples of storm water runoff during the sampled storm events. Chloride and zinc were observed in elevated concentrations in the ground water samples obtained from wells located in the two recharge basins receiving storm runoff from the Expressway. The SCDEC concluded that further investigation is obviously necessary to determine if runoff quality from the Long Island Expressway is comparable to the often reported major waste load attributed to heavy metals in runoff (Minei,1977).



PLAIN SEDIMENTATION–NATURAL IMPOUNDMENT SYSTEM
UNQUA POND MASSAPEQUA

G4-36



PLAIN SEDIMENTATION–NATURAL IMPOUNDMENT SYSTEM
UNQUA POND MASSAPEQUA

G4-37

Reproduced from
best available copy.

Reproduced from
best available copy.

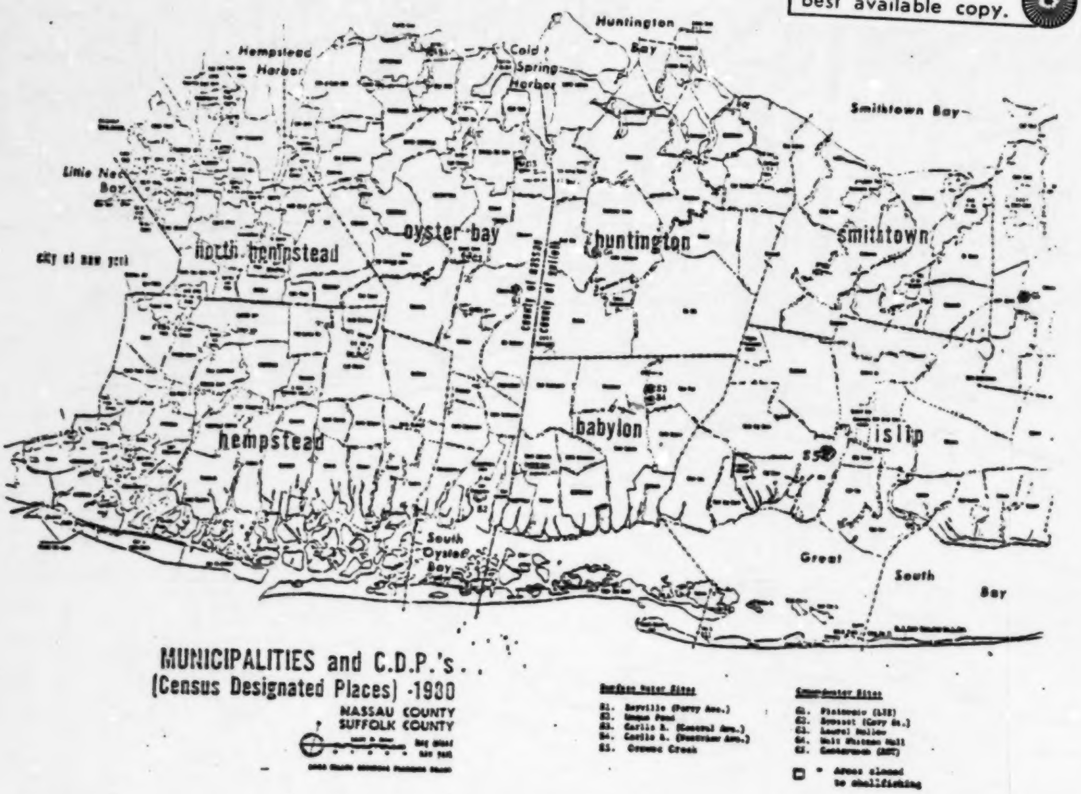


Figure 2 - Project Area and Sampling Sites

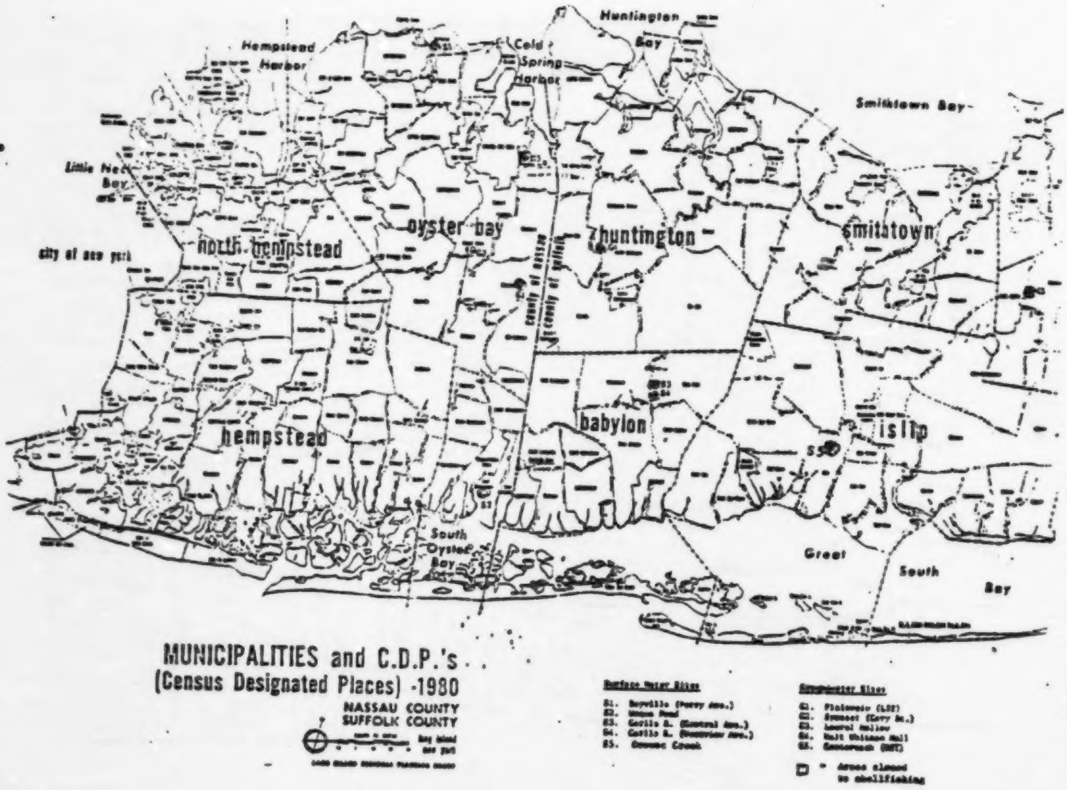


Figure 2 - Project Area and Sampling Sites

NATIONWIDE URBAN RUNOFF PROGRAM

NEW YORK STATE DEPARTMENT OF
ENVIRONMENTAL CONSERVATION

LAKE GEORGE, NY

REGION II, EPA

INTRODUCTION

Lake George is located in the eastern Adirondack Mountains of New York State and the southeastern portion of the Adirondack State Park not far from the Vermont State border (Figure 1). Sometimes called the Queen of American Lakes, its clarity is nearly unsurpassed in the United States.

Lake George lies mostly within Warren and Washington Counties: the northern tip of Lake George, at Ticonderoga, is within Essex County. Most of Lake George's commerce is located along the southwestern shores of the Lake, which are within Warren County. The commercial district is concentrated mainly at the southern tip of the Lake at Lake George Village.

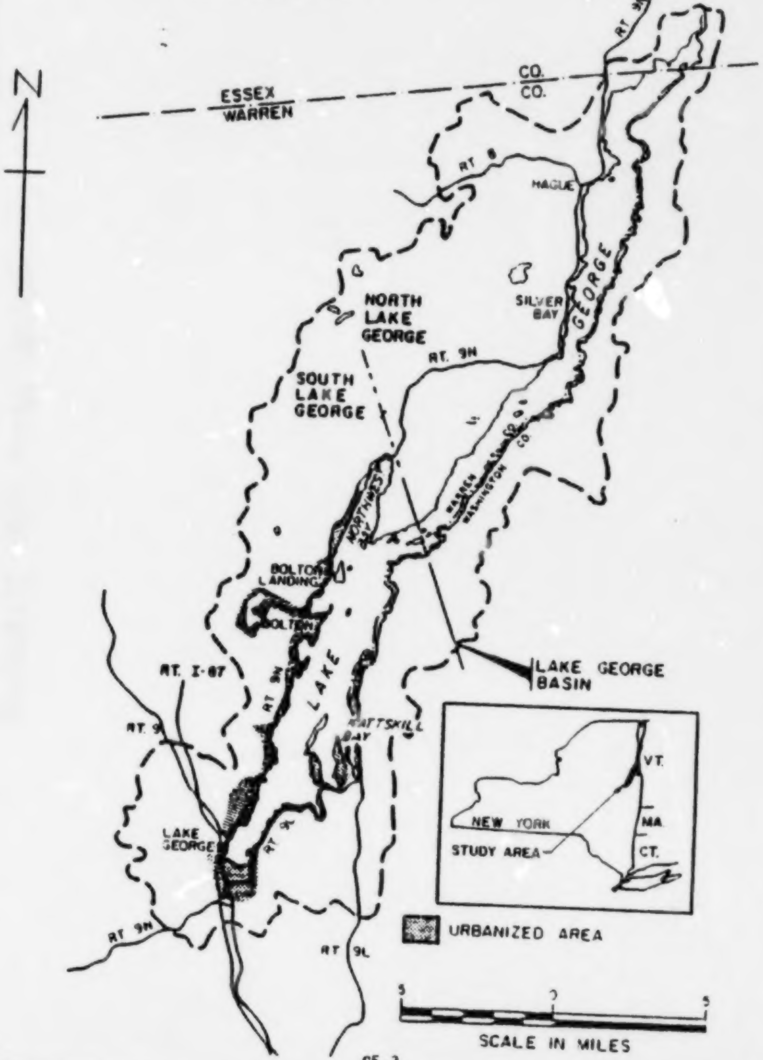
The major use of the waters of Lake George has been for recreation. It also provides a potable water supply for its peripheral inhabitants. In order to maintain the integrity of the waters, the State has designated it as a "Class AA-Special" water body. In addition, Title 17-1709 of the New York State (NYS) Environmental Conservation Law prohibits the discharge of sewage into waters of the Lake.

The population in Lake George is dominated by seasonal variations, since this lake is a popular resort area. The year round population in Bolton and Lake George Village, the two largest communities of south Lake George, is approximately 5000 persons. In the summer, this increases about tenfold to 50,000 persons. New York State projections for these two communities show the populations increasing to 6,000 permanent residents and 66,000 summer residents by the year 2000.

The recreational-based economies of communities in the Lake George region are heavily dependent upon maintaining a high level of water quality in the Lake. In recognition of the Lake as a unique resource, there has been a strong, long-term State and local commitment to protect and enhance the water quality of Lake George. This has resulted in a number of detailed studies of the Lake and in a long history of spirited public debate over the Lake's present and future quality.

Although the water quality of Lake George has been studied for over fifty years most of the emphasis has been placed on the physical and chemical nature of the open water. Only in the last decade has the lake's watershed been the object of scientific investigations, and almost all of this work has been in determining the water chemistry at the mouths of the ten or so major tributaries.

FIGURE 1 - STATE LOCUS AND PROJECT AREA OF LAKE GEORGE NURP



PHYSICAL DESCRIPTION

A. Area

Lake George is long and narrow; its major axis extends in a north, northeasterly direction. The Lake may be considered as two basins, commonly referred to as North and South Lake George, respectively. The South Lake is further divided into two basins, South and Central, on a morphometric and circulation basis; each contains a very deep section and several shallower areas. The deep South basin is also called Caldwell Basin.

Lake George has a lake surface which stands at 97 m above sea level and encompassess 71 km^2. The drainage basin surface area is 492 km^2. The lake averages 18.3 m in depth and varies in width from 1.6 km to 4.8 km along its 51.5 km length.

Most of the drainage basin is covered with shallow soil from glacial debris, with numerous outcroppings present. The lake shore is irregular, steep and rocky, with the lake at a rather low level, amid elevations of considerable height, creating a steep and fjord-like appearance. About 16 km^2 of a total of 492 km^2 is developed urban land, concentrated in the towns of Lake George, Bolton, Fort Ann, Hague, Queensbury, Dresdan, Putnam, Ticonderoga, and strip/shore developments along approximately half of the lake shoreline. (Figure 1) The rest of the area is sparsely-populated, deciduously-forested land with numerous conifers also present.

B. Population

According to Hetling (1974), the population of the Lake George watershed in 1970 was 32,484, of which 16,138 resided in sewered areas. The Town and Village of Lake George accounted for 50.5% of the total and 90.9% of the sewered population in 1970. However, of the total watershed population of 32,484, only 17.2% or 5,575 were year-round residents. Ferris et al. (1980) estimated a slightly smaller population for the watershed (30,160).

C. Drainage

Surface runoff into the lake is greatly affected by the physical characteristics of the basin, vegetation cover, areal variations and distribution of precipitation, soil moisture and groundwater, and development of the area by man. The shallow soil cover, abrupt topography, steepness of slopes, and short travel of runoff make storm runoff very rapid and tumultuous. The shape of the basin is elongated and this, coupled with the steep topography, creates a large number of streams with small drainage areas relative to the size of the lake. Of the 80 streams flowing into the lake, about one-fourth are intermittent. The water volumes in the North and South basins are equal at 2.11 billion cubic meters (1,689,600 acre-ft) for each. The average water retention time in the lake is 7.98 years.

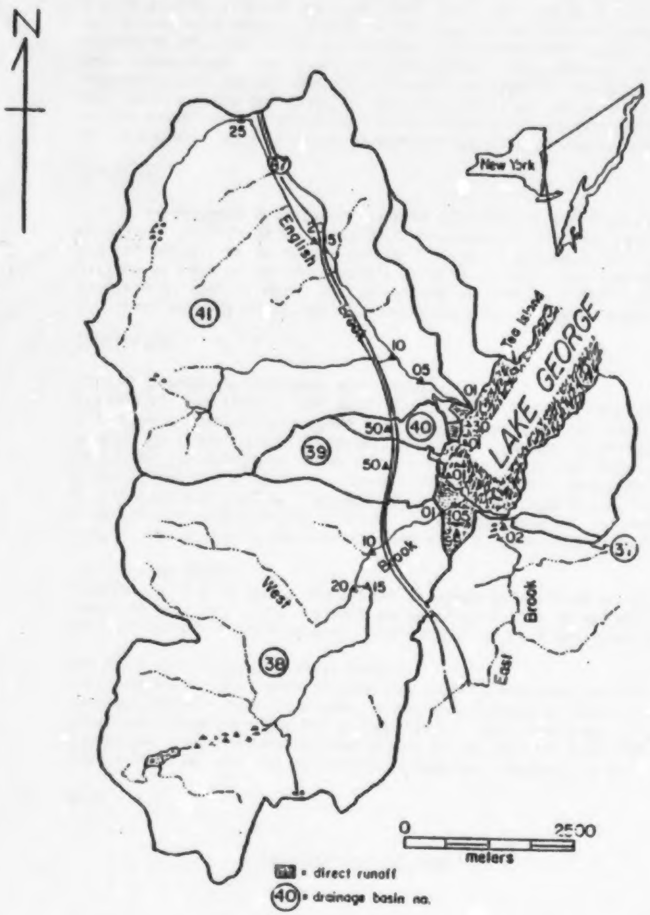
D. Sewerage System

The Village of Lake George is totally sewered with separate sewers and is served by a secondary sewage treatment plant utilizing trickling filters and sand beds. Phosphorus is removed by passage of the sewage through the sand beds whereupon the effluent is released as a subsurface discharge.

The Village of Bolton Landing, the other major concentration of population on the South Lake, is about 75% sewered with a separated system. Secondary treatment is provided by the same type of tricking filter and sand-bed system employed at Lake George Village.

The remainder of the homes and small commercial establishments scattered around the perimeter of the Lake are served by individual, on-lot disposal systems usually consisting of septic tanks and drainfields.

FIGURE 2 - LAKE GEORGE MONITORING BASINS AND SAMPLING SITES



PROJECT AREA

I. Catchment Name - Cedar Lane Storm Sewer (37)

A. Area - 76.2 acres.

B. Population - persons.

C. Drainage - The Cedar Lane storm sewer drains into East Brook approximately 10 feet south of a culvert carrying the Brook under Beach Road and into the Lake. The main channel is 1650 feet at a slope of approximately 996 ft/mile and for the last 328 feet flows through corrugated pipe.

D. Sewerage - 9.64% of the drainage area is served by separate storm sewers; 90.36% has no sewers.

Streets consist of .74 lane-miles of asphalt in good condition and .48 lane-miles of other materials in poor condition.

E. Land Use

4.48 acres (6%) is 0.5 to 2 dwelling units per acre urban residential, of which .62 acres (14%) is impervious.

27.52 acres (36%) is Linear Strip Development, of which 3.38 acres (12%) is impervious.

44.16 acres (58%) is Forest.

5% Imperviousness in entire drainage area.

II. Catchment Name - West Brook (38)

A. Area - 5337.6 acres.

B. Population - persons.

C. Drainage - West Brook, with several tributaries, flows northeasterly and enters the Lake at the south end. The main channel is 26400 ft. with a slope of approximately 433 ft/mile.

D. Sewerage - 0.27% of the drainage area is served by separate storm sewers; 99.73% of the catchment has no sewers.

15.29 lane-miles of streets are asphalt (92% in good condition, 5% in fair condition and 3% in poor condition); 18.7 lane-miles of streets are concrete (100% in good condition); .36 lane-miles are of other materials (53% in good condition and 47% in poor condition).

E. Land Use

22.04 acres (< 1%) is 0.5 to 2 dwelling units per acre urban residential, of which 2.91 acres (13%) is impervious.

119.37 acres (2%) is Linear Strip Development,
of which 18.43 acres (15%) is impervious.

15.60 acres (< 1%) is Urban Parkland or Open Space,
of which .33 acres (2%) is impervious.

166.20 acres (3%) is Urban Inactive, of which
0.62 acres (< 1%) is impervious.

75.29 acres (1%) is Urban (other),
of which 23.57 acres (31%) is impervious.

2.75 acres (< 1%) is Agriculture.

4894.17 acres (92%) is Forest,
of which 19.50 acres (< 1%) is impervious.

42.24 acres (1%) is Water, Lakes.

III. Catchment Name - Sheriff's Dock Storm Sewer (39)

A. Area - 552.3 acres.

B. Population - persons.

C. Drainage - Sheriff's Dock storm sewer discharges directly into the lake on the western shore at the south end through a 117 cm concrete pipe. The main channel is 5280 feet with a slope of approximately 610 ft/mile. The last 600 feet of the main channel and 1198 feet of a triburtary flow through metal pipe.

D. Sewerage - 3.66% of the drainage area is served by separate storm sewers; 96.34% of the drainage area has no sewers.

9.75 lane-miles of streets are asphalt (74% in good condition, 24% in fair condition, 2% in poor condition); 5.11 lane-miles of streets are concrete (100% in good condition).

E. Land Use

71.32 acres (13%) is 0.5 to 2 dwelling units per acre urban residential.
of which 18.10 acres (25%) is impervious.

32 acres (6%) is Linear Strip Development,
of which 12.23 acres (38%) is impervious.

7.04 acres (1%) is Urban Parkland or Open Space,
of which 0 acres (0%) is impervious.

14.08 acres (3%) is Urban Inactive,
of which 0 acres (0%) is impervious.

26.60 acres (5%) is Urban (other),
of which 4.53 acres (17%) is impervious.

401.28 acres (73%) is Forest,
of which 2.07 acres (1%) is impervious.

IV. Catchment Name - Marine Village Storm Sewer (40)

A. Area - 163.2 acres.

B. Population - persons.

C. Drainage - Originally an above-ground stream, reconstruction prior to 1926 channelized the stream and filled a wetland of considerable size. Presently Marine Village Storm Sewer originates in a farm pond (from which water discharges all year) and flows easterly, discharging through a metal pipe directly into the lake on the western shore approximately 2000 ft. from the south end. An intermittent tributary collects drainage from Interchange 22 of Interstate I-87. The main channel is 1980 ft. with a slope of approximately 887 ft/mile; approximately 1312 ft. of the main channel flow through corrugated metal pipe.

D. Sewerage - 7.31% of the drainage area is served by separate sewers; 92.69% has no sewers.

6.78 lane-miles of streets are asphalt (60% in good condition, 40% in fair condition); 3.31 lane-miles are concrete (100% in good condition); .26 lane-miles are of other materials (100% in fair condition).

E. Land Use

35.84 acres (22%) is 0.5 to 2 dwelling units per acre urban residential,
of which 12.38 acres (35%) is impervious.

17.28 acres (11%) is Linear Strip Development,
of which 6.55% acres (38%) is impervious.

15.36 acres (9%) is Urban Parkland or Open Space,
of which 0.42 acres (3%) is impervious.

14.72 acres (9%) is Urban Inactive,
of which 0.14 acres (1%) is impervious.

42.24 acres (26%) is Urban (other),
of which 25.99 acres (62%) is impervious.

37.76 acres (23%) is Forest,
of which 0.48 acres (1%) is impervious.

V. Catchment Name - English Brook (41)

A. Area - 5248 acres.

B. Population - persons.

C. Drainage - English Brook flows in a southeasterly direction, entering the lake on the western shore approximately 4000 ft. from the south end of the lake. The main channel is 36,630 ft. with a slope of approximately 2072 ft/mile. Highway, commercial and residential development adjoin the brook within 11,000 feet of the mouth.

D. Sewerage - .1% of the drainage area is served by separate sewers; 99.9% of the area has no sewers.

24.4 lane-miles of streets or highway are asphalt (100% in good condition); 35.03 lane-miles of streets or highway are concrete (100% in good condition).

E. Land Use

32 acres (1%) is 0.5 to 2 dwelling units per acre urban residential, of which 3.96 acres (12%) is impervious.

62.28 acres (1%) is Linear Strip Development, of which 7.29 acres (12%) is impervious.

8.96 acres (< 1%) is Urban Parkland or Open Space, of which 0 acres (0%) is impervious.

11.52 acres is Urban Inactive, of which 2.09 acres (18%) is impervious.

135.68 acres (3%) is Urban (other), of which 39.89 acres (29%) is impervious.

23.69 acres (< 1%) is Agriculture.

4956.77 acres (94%) is Forest, of which 20.56 acres (< 1%) is impervious.

1.84 acres (< 1%) is Water, Reservoirs.

14.69 acres (< 1%) is Wetlands.

PROBLEM

A. Local Definition (Government)

Every summer, inhabitants of New York City, Albany, Schenectady, Utica, Syracuse, Springfield, Hartford, New Haven, Montreal, and other northeastern cities concentrate in a narrow strip around the southern basin of Lake George. The population increases tenfold from about 5000 people to about 50,000 people, renewing annually, if temporarily, urban pressures upon the area. The reason for this migration is the quality of the environmental experience available. Central to that experience is the water quality of Lake George.

From 1974 to 1978, the algae population in South Lake George has increased logarithmically. The Lake is not eutrophic but the condition is incipient as reflected in the chlorophyll a data reported by Wood and Fuhs for 1978. The residence, or flushing, time in the southern basin of Lake George is eight years. Therefore, anything wrong with the Lake will take years to correct. If corrective actions are not taken in the next decade, an invaluable water resource impacting thousands of people may be lost. Reductions in recreational use caused by declines in water quality have been documented for a number of Lakes in New York State. Candarago Lake and Saratoga Lake are examples.

The water quality problem in Lake George appears to be related to phosphorus in the water body. Since anoxic conditions have not been observed, it is unlikely that the bottom sediment of the Lake is the source of the troublesome phosphorus. Rather, the phosphorus very likely is dissolved in the water discharges,such as urban runoff, coming from the land surrounding the Lake.

Incipient eutrophication is not the only problem facing the Lake. Dr. C.R. Goldman in his review of Lake George in 1978 presents the following account:

> "Mr. C.G. Suits of the Lake George Association has noted that bacterial pollution was the major problem in the Lake; total coliform counts for 1977 were 11,500, while the maximum allowable for water contact recreation is 2,400. Hazen and Sawyer (1975) also noted occasional high coliform counts ... the southern basin of Lake George has supported a noticeable growth of planktonic blue-green algae during the summer months. In addition, there have been more frequent complaints by residents about near-shore growth of other types of algae (Hazen and Sawyer 1977).
>
> The difference in limnological characteristics between the north and south basins provides the most substantial evidence that human impacts are causing changes in water quality. It is not likely mere coincidence that the south basin is much more populated and also more productive that the north basin (Aulenbach and Clesceri 1977; Ferris and Clesceri 1977a)."

Other existing problems include bacteriological levels that exceed water quality standards and sediment deposition which is impairing stream usage and contributing to lakeshore silting. Perhaps the most dramatic example of sedimentation is the emergence of deltas at the mouth of feeder streams. Sediments deposited in the streams and in the Lake are adversely affecting the food-producing, spawning and nursery potential of the Lake.

It appears that a significant part of any program to preserve the Lake's high water quality must be land-based control of urban runoff.

B. Local Perception (Public Awareness)

Widespread public concern for the water quality of Lake George is evident in the number of studies of the Lake conducted over the last dozen years, many of them sponsored by citizen organizations of one kind or another. Six studies of stream chemistry have been conducted and nine nutrient budgets have been prepared for the Lake since 1971 and the Lake George Park Commission has sampled storm sewers tributary to the Lake for bacterial quality since 1973. Much of this study was triggered by public alarm over extensive algal blooms which have occurred from time to time during the summer months. The Lake George Association, with a current membership of 3000 residents of the Lake George area, has been working since 1885 solely to preserve the quality of the Lake. A Lake George NURP Advisory Group comprised of 15 members representing the Lake George Park Commission, the Lake George Association, public officials, other public interest groups and the citizens at large regularly meets with project staff to review progress and provide comments and has conducted several public meetings to inform the communities about project-goals and accomplishments. Articles on urban runoff, its probable impact on the Lake and the need to control it regularly appear in the six local newspapers serving the communities surrounding the Lake.

PROJECT DESCRIPTION

A. Major Objectives

The major technical activities taking place in the Lake George study are:

1. Identification of all major stormwater sources in the highly developed southern portion of the Lake George Basin;
2. Quantification (in terms of concentration and load) of the major stormwater contaminants discharged to the Lake;
3. Assessment of the contribution of phosphorus and fecal bacteria to south Lake George; and
4. Baseline monitoring of selected tributaries.

Essentially these activities are intended to provide an assessment of the temporal and spatial generation of the various stormwater contaminants, their delivery to south Lake George, and the loadings attributable to stormwater, especially those for phosphorus. The findings will be used in the formulation of an overall urban runoff management strategy for the Lake to be funded at a later date from other sources.

Stormwater inputs to Lake George are generated by two major sources: 1) the densely populated residential/commercial area from Lake George Village to Bolton landing and, 2) the major highways (Interstate 87 - the Adirondack Northway - and New York State routes 9, 9L and 9N), that cross the watershed. Specific sources and impacted tributaries have been sampled and measured on an event basis to determine concentration and load of the several pollutants including complete scans for priority pollutants on a limited number of samples. The storm drains and streams designated for study give spatial distribution over the area such that major source zones can be identified.

The contribution of pollutants from both dry and wet atmospheric fallout is being determined in addition to the contributions from stormwater and septic systems.

B. Methodologies

An historical data review was completed and submitted to USEPA on December 1, 1980.

A storm sewer map was developed for the Village and Town of Lake George. This was essential to delineate the drainage of each catchment within the study area. Field surveys established the storm sewer system and the catchment boundaries.

Land use estimate have been updated using aerial photographs from 1948, 1958, and 1968, LUNR series maps (Shelton et al., 1973) and 1976 aerial photographs.

Verification of the land uses within the study area was carried out by NYSDEC personnel. Estimates for impervious areas have been calculated for all catchments within the study area.

The developed areas consist of private residences and commercial establishments related primarily to tourism and recreation. All travel, which is quite heavy, is essentially by automobile. There is no significant industry within the basin. The following land uses occur within the five basins chosen for runoff sampling and measurements:

- mixed residential/commerical;
- transportation (roads);
- urban open space; and
- forested, brush and open land.

The relatively large amount of undeveloped land which surrounds the urban areas constitutes a major part of most of the monitored basins. For this reason an additional monitoring site was established during the summer of 1981 upstream of the urban area in one of the basins to determine background runoff loadings for comparison with the loadings generated within the urban areas.

A total of forty atmospheric deposition samples were submitted for chemical analysis during the first year of the study. These include twenty-five wetfall samples, six dryfall samples and nine samples from the bulk collector.

The monitoring of priority pollutants was not carried out during the first year, but is scheduled for completion by June, 1982. Sample collection will be carried out by NYSDEC personnel and sample analysis will be conducted by laboratories at the NYS Department of Health.

A review of historical data for the near-shore area of Lake George was completed during the first year. Water quality in the near-shore area has received little previous attention. Most of the sampling programs have been carried out in the deeper waters. Therefore, a limited sampling program for near-shore areas of the Lake was established to determine baseline water quality and the response of Lake water quality to storm events. To determine the impact of stormwater runoff on the Lake, the phytoplankton community response was analyzed. Algal assays were conducted to determine the availability of nutrients in the open waters. Lake sampling was conducted only during the first year of the project.

C. Monitoring

The study area consists of two stream watersheds (West Brook and English Brook) and three storm sewer catchments (Cedar Lane, Sheriff's Dock and Marine Village) located at the extreme southern end of Lake George. A sampling station recently established to determine runoff loadings from undeveloped open land is located in the Sheiff's Dock catchment west of the Village of Lake George and Interstate I-87.

The major land use within the West Brook watershed is forests. Urban areas constitute a small part of the area (7.5%), all located immediately adjacent to the Lake. The predominant land use in the English Brook watershed is forest (91.7%).

All development is located adjacent to the Brook, is highway, commercial or residential in nature and is within two miles of the mouth. The predominant land uses within the Cedar Lane storm sewer drainage are forest (58.0%) and urban (42.0%), approximately 86% of the latter being commercial. In the Sheriff's Dock drainage basin, forests constitute the greatest proportion of land use (72.6%). Urban areas, although only 27.4% of the total basin, are concentrated east of Interstate I-87 within the Village of Lake George and are 44.6% impervious. Urban areas constitute the predominant land use (76.9%) within the Marine Village basin, approximately 60% of which falls within the boundaries of the Village of Lake George. The total impervious area for this portion of the drainage basin is 25.45%. The remaining land area is forested (23.1%).

Atmospheric sampling, including wetfall/dryfall and bulk, was conducted originally at a point within the West Brook drainage basin near the Lake but has been shifted to a location within the Cedar Lane Storm Sewer basin for the remainder of the project due to interference from trees at the first location.

Collected samples are analyzed for the following constitutents: nitrogen, phosphorus, suspended solids, chloride, sodium, lead, bacteria, pH, conductivity, alkalinity and temperature. In addition, other parameters listed in the USGS/EPA Urban Hydrology Studies Program will be analyzed for as necessary.

Equipment

Location	Type	Equipment
Lake George V. Village	Atmospheric Fallout	Aerochemetrics, Inc., wet/dry deposition collector, bulk precipitation collector and weighing bucket recording precipitation collector.
West Brook English Brook	Streams	Manning S-4050 automatic sampler, liquid-level actuated STACOM-7735 gas purge servo manometer, Fisher-Porter ADR-350, and Stevens chart recorder type A35.
Cedar Lane	Stormsewer	ISCO 2100 automatic flow proportional sampler, ISCO 170 flow meter with ISCO 1710 printer, 53 cm Palmer-Bowlus Flume.
Sheriff's Dock	Stormsewer	Manning S-4050-2 automatic sampler, liquid-level actuated or flow proportional, Marsh-McBirney Flowmeter Model 250.
Marine Village	Stormsewer	Manning S-4050 automatic sampler, liquid-level actuated or flow propotional, Marsh-McBirney Flowmeter Model 250.

D. Controls

The original work plan for this project provided for the evaluation of control measures and development of a stormwater control management plan in the second and third years of the project if the sources of phosphorus and other nutrients entering the southern portion of the Lake could be pinpointed as a result of the first year's monitoring and analysis efforts. Because isolation of those sources proved to be more difficult than originally anticipated, it was decided to drop evaluation of controls and development of a management plan in favor of modifying and continuing the monitoring and analysis tasks.

IRONDEQUOIT BAY, NEW YORK

INTRODUCTION

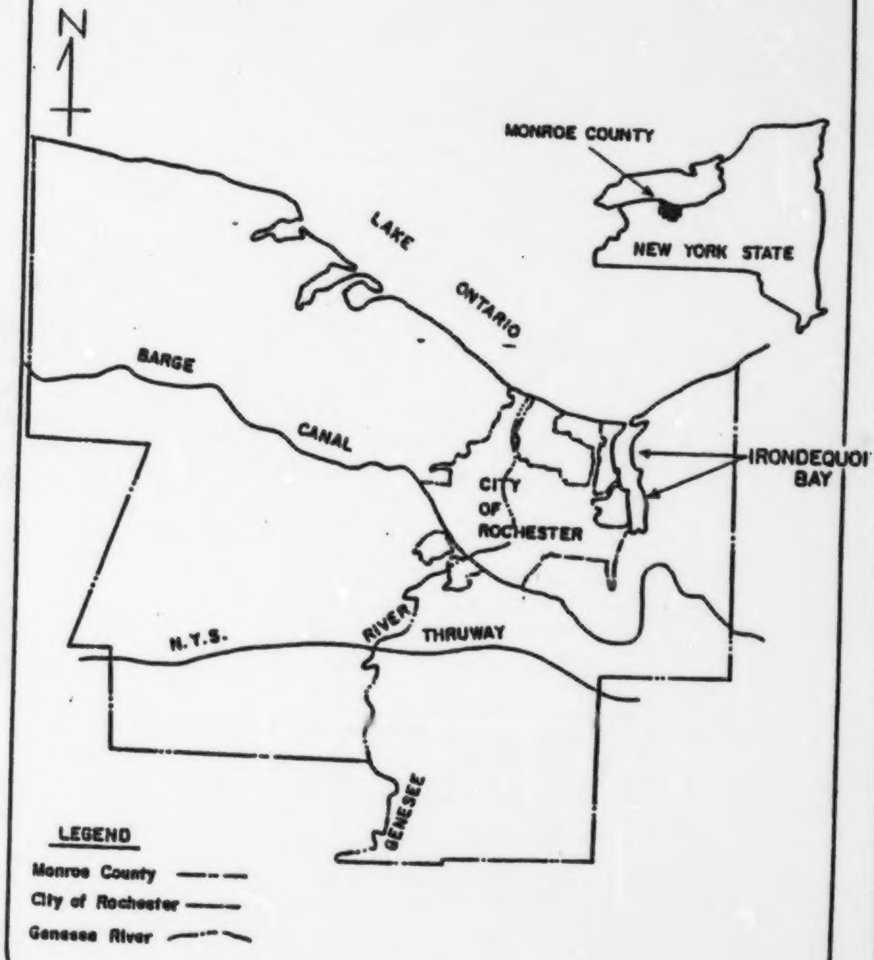
Irondequoit Bay is one of many bays of Lake Ontario located within New York State. It is a prime water resource for Monroe County in terms of recreational potential. Figure 1 shows the general location of the Bay within Monroe County. A quarter of a million people presently inhabit the area tributary to Irondequoit Bay. It is truly an urban receiving water body, being completely surrounded by rapidly expanding urban development.

The Bay is a relatively shallow body of water bordered by low-lying areas. The stormwater generated from the eastern portion of the City of Rochester and much of the southeastern portion of Monroe County drains to Irondequoit Bay. Combined sewer overflow (CSO) discharges also enter the Bay from the City of Rochester. These factors have led to a progressive eutrophication of the Bay which has seriously restricted its recreational potential.

The degraded water quality of Irondequoit Bay and the condition of the benthos severely interfere with its use for bathing, boating, and fishing. Presently, the Bay is classified as Class "B" waters by the New York State Department of Environmental Conservation (NYSDEC). Public surveys, however, have indicated widespread support for restoring the Bay sufficiently to support earlier uses such as contact recreation.

A comprehensive sewer study conducted during the late 1960s recommended a water quality management program requiring complete diversion from the Bay of all sewage treatment plant (STP) discharges and CSOs from the City of Rochester. The diversion of STP discharges has now been fully completed and a program to reduce drastically CSO discharges to the Bay is well underway. The expected improvement in water quality should move the Bay a long way toward restoration of its identified best uses - fishing and swimming. However, there is concern by local officials that urban stormwater runoff, if allowed to continue to enter the Bay uncontrolled, will deter the full restoration process.

FIGURE 1 - STATE AND COUNTY LOCUS OF IRONDEQUOIT BAY
NURP PROJECT



PHYSICAL DESCRIPTION

A. Area

Irondequoit Bay is an impoundment 4 miles in length and between 0.25 and 1.25 miles in width located 3.7 miles northeast of the center of the City of Rochester. At the north end, it is separated from Lake Ontario by a sandbar. Its scenic value enhances neighboring real estate, its hillsides have great potential as public parks and, despite large stormwater and CSO inputs, it is heavily used for various recreational purposes. The urban area of the basin generally comprises that portion north of the NYS Barge Canal (cf. Figure 2). Suburban tract development is rapidly advancing into former agricultural areas in the portion of the basin immediately south of the Canal and extending to Interstate 90. Farming dominates in the eastern portions of Penfield and Perinton, the southern half of Pittsford, and essentially all of Mendon, Victor, and West Bloomfield.

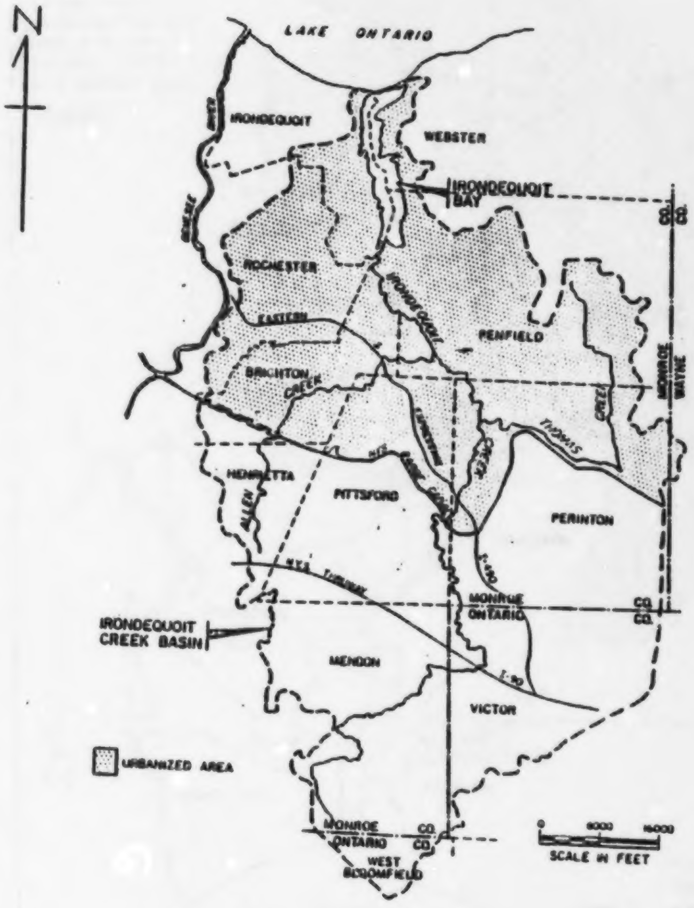
B. Population

The southeast portion of the City of Rochester and nine Monroe County townships lie in the Irondequoit Bay (IB) drainage basin. The population of the basin is difficult to determine accurately because: (1) boundaries of the watershed and of the census districts never coincide, and (2) the East Side Trunk Sewer (within the City of Rochester) diverts a portion of the sanitary and storm runoff towards the Genesee River away from the Bay, which reduces the IB drainage basin population. Based on 1970 U.S. census data, total basin population was estimated at 240,000. Assuming complete diversion of Rochester sewerage, the effective population would be about 140,000.

C. Drainage

The drainage area is characterized by gently rolling countryside laced with streams of various sizes, all of which feed into Irondequoit Creek. The Bay itself is bordered by steep, wooded hillsides. The Irondequoit Bay Drainage Basin (Figure 2) measures 22 miles on the north-south axis and 13 miles in width, with a total drainage area of about 168 square miles in Monroe, Ontario and Wayne Counties. The major hydrologic features of the basin are 1800-acre Irondequoit Bay and its tributary, Irondequoit Creek. The Creek is about 37 miles long, drains an area of 136 square miles, and flows from 770 feet to 246 feet elevations with gradients of about 20 feet/miles above the Barge Canal and about 11 feet/miles below. The lower 2-1/2 miles of the Creek pass through a narrow, marshy valley. Some 40 streams are tributary to Irondequoit Creek, the largest being Allen Creek and Thomas Creek. Continuous records for stream flow in Irondequoit Creek are not available, but a stage gauge has existed on Allen Creek about 1 mile upstream from Irondequoit Creek since 1959. An average discharge rate of 168 cubic feet per second near the mouth of the Irondequoit Creek may be calculated based on the ratio of the Allen Creek and Irondequoit Creek drainage areas.

FIGURE 2 - PROJECT AREA



Irondequoit Bay is about 4 miles long and varies between 1/4 and 1-1/4 miles in width. The Bay lies at the mouth of a pre-glacial river valley with slopes rising on either side to about 150 feet over the present water level. Depths vary between very shallow marshes at the northern and southern extremities and 75 feet in the central basin. Approximately 50% of its area lies over shallows less than 10 feet deep. The outlet to Lake Ontario passes under railway and highway bridges and is restricted by a sand spit to an opening 50 feet wide and 200 feet long. The depths at the outlet range between a few inches and 4 feet. Flow at the outlet is variable and restricted, depending on oscillations in Lake levels due to wind direction and barometric pressure differences as well as on variations in the discharge of Irondequoit Creek. Mixing between the Bay and Lake Ontario is limited.

D. Sewerage System

The area within the Rochester city limits (figure 2) in the northwestern corner of the drainage area is served by combined sewers which are part of the $80 million program to reduce CSOs to a once-in-five-year frequency. The urbanized areas outside the City of Rochester and excluding the township of Mendon and Victor are served by separate storm sewers which discharge into the creek system and by sanitary sewers which, along with the combined sewers within the City limits, flow to the Van Lare treatment plant, Rochester's 250 MGD secondary treatment facility which discharges directly into Lake Ontario. The areas of Mendon and Victor townships lying within the Irondequoit Creek watershed are rural and unsewered.

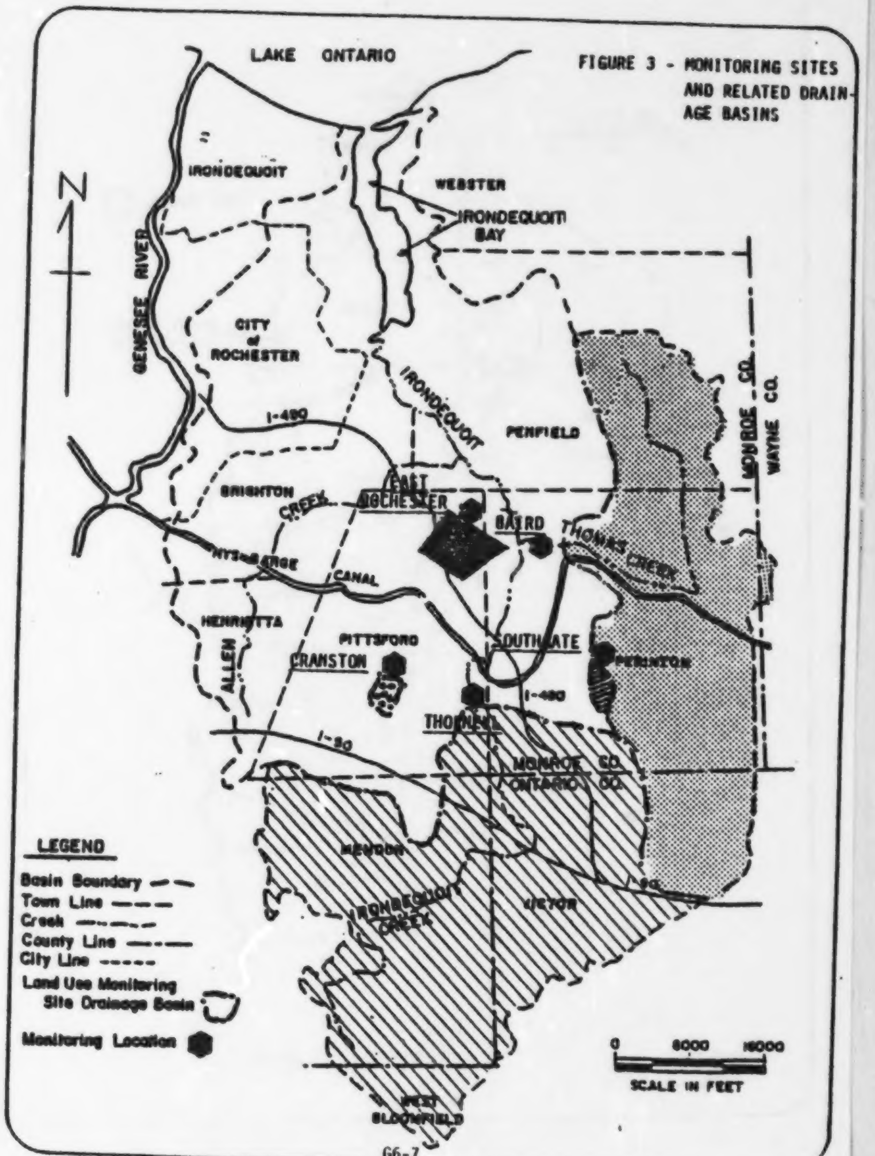


FIGURE 3 - MONITORING SITES AND RELATED DRAINAGE BASINS

PROJECT AREA

I. Catchment Name - East Rochester.

A. Area - 384 acres.

B. Population - 6836 persons.

C. Drainage - This catchment area has a representative slope of 58.08 feet/mile, 90% served with curbs and gutters and 10% served with swales and ditches. The storm sewers approximate a 15.84 feet/mile slope and extend 7600 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 25.09 lane miles of asphalt, 75% of which is in good condition, 20% of which is in fair condition, and 5% of which is in poor condition. There is no concrete or other roadway in the catchment.

E. Land Use

384 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 146 acres (38%) is impervious.

II. Catchment Name - Baird Road (Thomas Creek)

A. Area - 18,240 acres.

B. Population - 24,618 persons.

C. Drainage - This catchment area has a representative slope of 232.32 feet/mile, 8% served with curbs and gutters and 2% served with swales and ditches. The storm sewers approximate a 15.84 feet/mile slope and extend 56,496 feet.

D. Sewerage - Drainage area of the catchment is 10% separate storm sewers and 90% unsewered.

Streets consist of 186.37 lane miles of asphalt, 90% of which is in good condition and 10% of which is in fair condition, and 19.03 lane miles of other material, 90% of which is in good condition and 10% of which is in fair condition.

E. Land Use

18,240 acres (100%) is < 0.5 dwelling units per acre urban residential, of which 1920 acres (11%) is impervious.

III. Catchment Name - Southgate

A. Area - 177.2 acres.

B. Population - 260 persons.

C. Drainage - This catchment area has a representative slope of 300.96 feet/mile, 58% served with curbs and gutters and 3% served with swales and ditches. The storm sewers approximate a 36.96 feet/mile slope and extend 2150 feet.

D. Sewerage - Drainage area of the catchment is 60% separate storm sewers and 40% no sewers.

Streets consist of 2.75 lane miles of asphalt, 95% of which is in good condition and 5% of which is in fair condition.

E. Land Use

177.2 acres (100%) is Shopping Center of which 37.7 acres (21%) is impervious.

IV. Catchment Name - Thornell Road

A. Area - 28,416 acres.

B. Population - 5950 persons.

C. Drainage - This catchment area has a representative slope of 279.84 feet/mile, .25% served with curbs and gutters and 4.75% served with swales and ditches. The storm sewers approximate a 15.84 feet/mile slope and extend 82,360 feet.

D. Sewerage - Drainage area of the catchment is 5% separate storm sewers and 95% no sewers.

Streets consist of 255.75 lane miles of asphalt, 90% of which is in good condition and 10% of which is in fair condition. In addition there are about 13.62 lane miles of concrete, of which 90% is in good condition and 10% is in fair condition, and 25 lane miles of other material, of which 90% is in good condition and 10% is in fair condition.

E. Land Use

28,416 acres (100%) is Agriculture, of which 1051 acres (4%) is impervious.

V. Catchment Name - Cranston Road

A. Area - 167.6 acres.

B. Population - 900 persons.

C. Drainage - This catchment area has a representative slope of 174.24 feet/mile, 68% served with curbs and gutters and 22% served with swales and ditches. The storm sewers approximate a 84.48 feet/mile slope and extend 2850 feet.

D. Sewerage - Drainage area of the catchment is 89.6% separate storm sewers and 10.4% no sewers.

Streets consist of 8.67 lane miles of asphalt, 100% of which is in good condition.

E. Land Use

167.6 acres (100%) is 0.5 to 2 dwelling units per acre urban residenti of which 36.3 acres (22%) is impervious.

PROBLEM

A. Local Definition (Government)

A dense algal crop occupies the surface waters of the Bay continuously from early May to mid-October. Deep sediments (characterized by citizens as "black muck") underlie the Bay waters. Spring mixing in the Bay is often incomplete and in the fall is often delayed. These conditions have been related to the accumulation of roadway de-icing salts in the deeper waters. Algae and other organic matter sink to the bottom of the Bay, where decomposition during winter and summer stratification consume all of the dissolved oxygen in the bottom waters and generate high concentrations of ammonia, phosphate, and hydrogen sulfide.

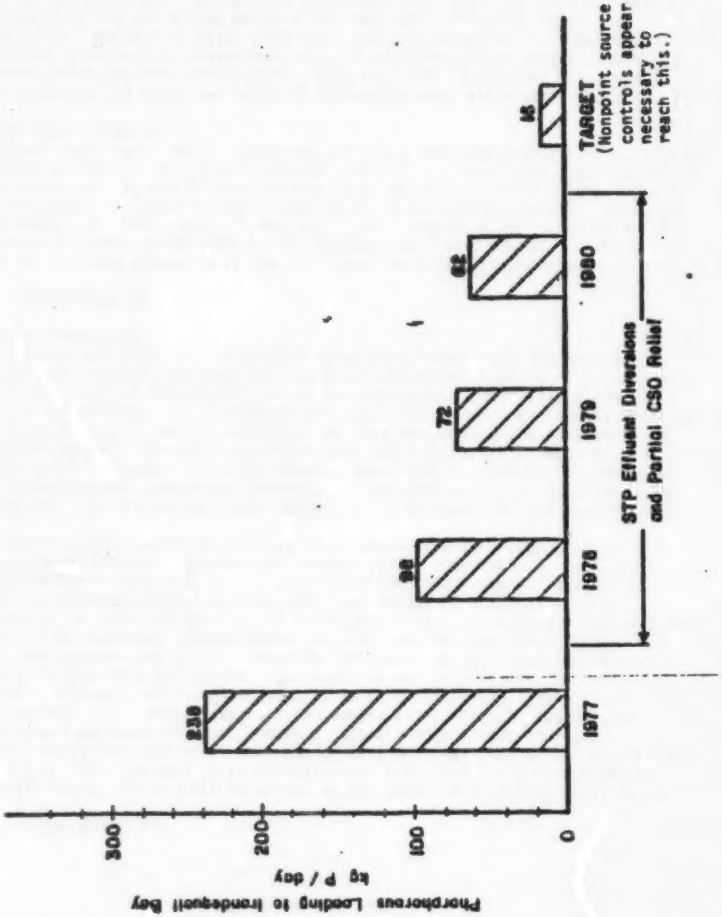
A comprehensive sewer study conducted during the late 1960s recommended a water quality management program to enhance water quality in the Bay. The program, which was eventually adopted, required complete diversion from the Bay of all sewage treatment plant (STP) discharges and CSOs from the City of Rochester. Extensive limnological studies of the Bay ecosystems were also conducted. These studies provided the data base to properly evaluate the impact of the proposed wastewater diversion program. All of these studies indicated that Irondequoit Bay was beginning to approach a nutrient limiting condition and that a significant reduction in phosphorous loadings would be necessary to arrest and reverse the water quality degradation of the Bay.

Figure 4 indicates the dramatic reduction in phosphorus loadings to the Bay which has been accomplished by the STP effluent diversions and partial CSO relief. The average daily phosphorous loading to the Bay has decreased from 238 kg P/day to 62 kg P/day since 1977 as the discharges from 16 STPs have been diverted. Additional reduction will be realized when an ongoing Rochester CSO pollution abatement program is completed. This program involves construction of the Culver-Goodman Tunnel complex on the east side of the city. While completion of this program is expected to reduce phosphorous loadings further, it will not lower them to the 16 kg/day level required to control the algal productivity of the Bay. Consequently nonpoint source controls are essential to restore, and maintain acceptable water quality in the Bay.

Specifically, there is concern by local officials that urban stormwater runoff, if it continues to enter the Bay uncontrolled, will deter the full restoration process and may even reverse it.

While much is known about Irondequoit Bay from previous studies, the impact of further pollutant loading reductions by the control of urban stormwater runoff has yet to be adequately demonstrated. The relative magnitude of the remaining urban runoff pollutant loading and the cost-effectiveness of further reductions require further study. Furthermore, if it appears cost-effective to reduce the urban stormwater runoff component of the Bay's pollutant inputs, evaluations must continue in order to formulate control strategies for dealing with the urban runoff problem.

FIGURE 4 - REDUCTIONS IN PHOSPHORUS LOADINGS TO IRONDEQUOIT BAY FOLLOWING STP EFFLUENT DIVERSIONS AND PARTIAL CSO RELIEF



B. Local Perception (Public Awareness)

Clear indication of the extent of citizen concern for water quality in the Bay has been shown by public support of the $130 million already spent to divert STP effluents from the Bay and of the $80 million presently being spent to reduce CSOs. Newspapers, radio and television consider efforts to clean up the Bay newsworthy and generally give such efforts excellent coverage, another indicater of widespread citizen interest in the water quality of the Bay. To some extent, public concern for the Bay is a matter of re-education as water quality in the Bay has been on the decline for many years and its widespread use for contact recreation is beyond the personal memories of most of its current citizens. As word of the NURP study has spread, however, citizen interest in the future improvement of the Bay has grown markedly.

PROJECT DESCRIPTION

A. Major Objective

Simply stated, the primary objective of the Irondequoit Bay National Urban Runoff Program (IBNURP) is to establish the significance of the impact of urban runoff upon the water quality of Irondequoit Bay and to put it into perspective with other nonpoint sources. The problems associated with Irondequoit Bay - hypolimnetic oxygen depletion, turbidity, and adverse fishery impacts - result from the grossly over-productive status of the Bay and have been well documented. The problems are very clear; the causes of the problems are not clear. Controls for diverting all point source discharges involved the expenditure of $130 million and are presently operating. Controls for reducing CSOs to a once-in-five-year frequency have been designed and are presently under construction. The amount of reversal in Bay eutrophication that will result from these controls, however, has yet to be fully determined. The missing element now is assessment of the significance of urban stormwater runoff as a contributor to eutrophication.

A second, and equally important objective, is to determine the effectiveness of primarily non-structional controls in reducing the impact of urban runoff. Accordingly, various management options involving Best Management Practices (BMPs) which are currently being evaluated by a USEPA Great Lakes Initiative Grant Program for the City of Rochester will be reviewed for applicability to the Irondequoit Bay drainage basin. The effectiveness of control measures will be evaluated separately, and in various combinations. Since commitments have already been made to both point source and CSO control, the merits of urban runoff control can be more definitively specified and understood more pragmatically.

B. Methodologies

The sources and magnitude of the pollutants must be determined before specific control measures can be formulated to abate the present storm-induced contamination in runoff entering the Bay. The Irondequoit Bay drainage basin is comprised of urban, suburban, and rural or agricultural areas. Therefore, one major task of the overall program is to determine the magnitude and frequency of specific pollutant loadings from typical urban land uses, including highways and roads, and to differentiate these loadings from those originating from undeveloped land.

To determine the pollutant loadings associated with different land uses, five monitoring sites were established. Each site has an associated tributary drainage area that is relatively small in relation to the entire Irondequoit Bay basin. Because of this, boundaries for each area can be accurately established and the runoff measurements and sampling easily conducted. Monitoring of small, well-defined watersheds will allow for reliable and accurate pollutant runoff determinations and easy identification of the sources of these contaminants. Estimates of present and future runoff loads to the Bay will be based on transferring and extrapolating the data collected from these five different land use sites.

At present, a full year's monitoring program, incorporating both dry weather and storm samples and seasonal variations, has been conducted at all five land use sites. Less frequent monitoring has also been conducted at two "junction" sites draining larger sections of the overall Irondequoit Bay basin and at a wetlands site a few hundred yards from the point where Irondequoit Creek discharges into the Bay and which effectively drains the entire basin. The same monitoring program will be continued for a second year.

In conducting this project, the Vallenweider eutrophication model will be adapted so that the contribution of urban runoff to Bay eutrophication can be evaluated. The model will also be used to evaluate the effectiveness of overall runoff management schemes on the water quality of the Bay. A watershed model will be used to establish the relationship of rainfall to stormwater runoff and pollutant loadings. Watershed response, which transfers precipitation input into runoff output, is determined by land use and other physical characteristics which can be estimated during model calibration. One-demensional tributary models that address advective and dispersive process components will be used to simulate the transport of loads by the tributaries to the Bay. Constraints will be imposed on the models to simulate the action of control measures and thereby establish their relative effectiveness.

C. Monitoring

Sample collection and analysis for the Irondequoit Bay NURP are being performed by the U.S. Geological Survey (USGS) and the Monroe County Health Department (MCHD).

Table 1 summarizes the land uses and relative sizes of the five primary sampling sites:

TABLE 1. LAND USE MONITORING SITES

Monitoring Location	Basin Tributary	Drainage Area mi^2	Land Use
Thornell Road	Irondequoit Creek	44.4	Rural
laird Road (BOCES)	Thomas Creek	28.5	Mixed
ranston Road	Irondequoit Creek	0.31	Middle density residential
outhgate Road	White Brook	0.36	Commercial
ast Rochester	Storm sewer to Irondequoit Creek	0.61	High density residential

Baseflow samples are collected at all sites using methods described by Guy and Norman to define non-storm or background concentrations at gaged sites.

Precipitation quality is determined at three sites using an Aerochemetrics Inc. Model 301 wet/dry fall collector. A minimum of one continuous precipitation quantity gage is located in each watershed sampled. Because of the large basin area, a network of daily gages for rainfall quantity are operated in the Irondequoit Bay NURP to supplement continuous precipitation data.

The constituents analyzed in each sample are:

Suspended solids,
Particle size analysis,
Specific conductance,
pH,
Dissolved Solids,
Dissolved NO_2, NO_3-N,
Dissolved Kjeldahl-N,
Total Kjeldahl-N,
Dissolved Phosphorus-P,
Total Phosphorus-P,
Dissolved Sodium-Na,
Dissolved Calcium-Ca,
Dissolved Magnesium-Mg,
Dissolved Potassium-K,
Dissolved Chloride-Cl
Dissolved So_4
Alkalinity as $CaCo_3$,
Dissolved Organic Carbon,
Suspended Organic Carbon,
Chemical Oxygen Demand,
5-Day BOD,
Ultimate BOD, and
Fecal Coliform.

Sampling and streamflow equipment at the Irondequoit Bay collection sites are maintained by USGS and Monroe County personnel. All samples are returned as soon as possible after collection to the Monroe County Health Department Laboratories for further processing, i.e., filtering, splitting, preservation, etc. The use of this lab provides a nearby well equipped facility with well trained personnel for sampling processing.

Equipment

Flow monitoring at four of the five land use sites is accomplished by converting a stage or depth of flow, the primary measurement, into a flowrate according to a calibrated and verified stage/discharge relationship. At the East Rochester site, flow is computed directly by a Marsh-McBirney electronic head and velocity meter. Depth is computed by a pressure sensor, whereas, velocity is determined by an ultrasonic meter. All water quality sampling is accomplished by the use of Manning Corporation flow proportional samplers. Each of the five monitoring sites also measures precipitation by a recording tipping-bucket rain gauge. A summary of the type of sampler and recording procedure used for runoff flow monitoring and water quality sampling is presented in Table 2.

TABLE 2. FLOW MONITORING AND SAMPLING METHODS

Monitoring Location	Flow Monitoring	Sampling	Rainfall
Thornell Road	Mercury manometer bubbler gage-records in graphical and 15-min digital form.	Manning Sampler stage-activated or flow-proportional samples.	Volumetric 5 min digital output
Baird Road (BOCES)	Stilling well-float method-records in graphical and 15 min digital form	←—— Same as Thornell Road	
Cranston Road.	Same as Thornell Road - except records in 5 min digital form	←—— Same as Thornell Road	
Southgate	Same as Cranston Road ——→		
East Rochester	Marsh-McBirney flowmeter	Same as Thornell Road	

Controls

A wide variety of control measures have been investigated for possible use in the Irondequoit Bay basin. Probable candidates include increased use of porous pavement in developing areas, improved solid waste management procedures, erosion and sedimentation control regulations, chemical use ordinances and related public information programs, modification of highway deicing practices, industrial spill control ordinances, miscroscreening and swirl concentrators (depending upon monitoring results with regard to particles size and associated nutrients), detention and retention basins and swale drainage. Because of the presence of a large wetlands area near the mouth of Irondequoit Creek, this technology offers great promise in this watershed. Considerable discussion has already addressed the possibility of installing a control structure on the outflow from the wetlands to maximize detention time and, presumably, nutrient uptake. However, this would have to be done carefully as, according to some of the available literature, microbial activity is the most important mechanism for phosphorus removal and this activity decreases if the soil is submerged and becomes anaerobic. In any case, because of the length of time required for adequate evaluation it is highly unlikely that significant results can be obtained by the end of the NURP project period and therefore wetlands evaluation would have to be conducted as a separate project.

NATIONWIDE URBAN RUNOFF PROGRAM

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS

Water Resources Planning Board
In Association With
Northern Virginia Planning District Commission
And The
Virginia Polytechnic Institute and State University

REGION III, EPA

INTRODUCTION

The metropolitan Washington area extends for approximately 2400 square miles centered on the District of Columbia. The major receiving waters include the Potomac River and Estuary, the Patuxent River and the Occoquan Creek and River. These rivers and estuary systems provide important freshwater and low salinity spawning aras for anadromous fish populations off the Atlantic coast from Maine to Florida. Further these river systems provide the source of a valuable product, drinking water, for the entire metropolitan Washington area.

The water quality problems include destruction of spawning areas, reduction in storage capacity of the Occoquan reservoir from excessive upstream erosion, and eutrophic levels of algae production.

The project is (1) evaluating BMP effectiveness of source, volume and detention controls, (2) determining capital and operation, maintenance and repair costs of BMP's, (3) scanning 128 priority pollutants, (4) refining runoff data in central business district areas, (5) monitoring and analyzing the contribution of atmospheric sources to urban nonpoint source loads, (6) conducting critical watershed studies to apply runoff relationships, refine data transferability and identify nonpoint source management options, and (7) conducting a public participation program.

The Washington NURP project participation represents a unique cooperative ventures of government and the business community. The project is being coordinated and administrated by the Metropolitan Washington Council of Governments (COG) and its Water Resources Planning Board (WRPB).

Since 1975, the WRPB has been responsible for areawide wastewater management planning for the metropolitan region under provisions of Section 208 of the Federal Water Pollution Control Act Amendments of 1972. The WRPB is composed of representatives of the executive and legislative branches of COG's 16 member jurisdictions. Members also include representatives from the State of Maryland, Virginia, and the District of Columbia (through its responsibility for state certification of the 208 areawide water quality management plan); the Interstate Commission on the Potomac River Basin (ICPRB), and the Northern Virginia Planning District Commission (NVPDC).

Technical staff assistance of the WRPB is provided by the COG Department of Environmental Programs (DEP). DEP is responsible for all of the project's program management activities. Other COG participating departments include its Office of Computer Services and Office of Public Participation.

The project was developed and is being carried out in association with the Northern Virginia Planning District Commission (NVPDC) and the Virginia Polytechnic Institute and State University (VPI). VPI is responsible for all sample collection and analysis, with the exception of priority pollutant scan analysis, which has been subcontracted to a private research/engineering firm. NVPDC is responsible, in conjunction with VPI and COG, for evaluating lab data from specified BMP monitoring activities and land use/runoff correlation studies. VPI and NVPDC are generally recognized as national leaders in research and data applications involving nonpoint source assessments.

Both agencies were associated with COG in earlier 208-related studies and planning efforts.

The National Association of Home Builders (NAHB) and the Northern Virginia Builder's Association (NVBA) are also providing financial support and periodic technical input to this project. To date, the associations have provided assistance in site selection and development of unit cost survey information for the BMP pollutant removal efficiency and cost studies. The NAHB and NVBA have also participated on the WRPB Nonpoint Source Task Force (NPSTF), a group which includes engineers and planner from area local and state governments as well as business and citizen group interests.

PHYSICAL DESCRIPTION

A. Area

The Washington, D.C. metropolitan region is an area of approximately 2,400 square miles, located within the Potomac River Basin and a major portion of the Patuxent River Basins (See Figure 1). Its principal urban areas are situated at the head of the Potomac Estuary. Free-flowing sections of the Potomac River provide 60 percent of the region's drinking water, with one of the estuary's major tributaries, Occoquan Creek, supplying an additional thirteen percent. The upper Potomac Estuary and its tributaries constitute an important freshwater low salinity spawning area for anadromous fish of the Potomac and Chesapeake Bay.

A majority of the region falls within the piedmont and coastal plain geologic formations. The region's clay/sandy silt loam soils, found on both formations, are considered severely erosion prone. Figure 2 depicts the region's generalized soil groupings.

B. Population.

The Washington, D.C. region has a current population of approximately 3 million persons. Population growth has traditionally been greatest in area suburbs and recent growth trend assessments predict this trend will continue, with the suburbs projected to show over a 40 percent increase in population by the year 2000 as compared to an 11 percent rate of growth in the inner urban core (District of Columbia, Arlington County).

Table 1 shows the current (1977) distribution of land use throughout the region, and provides a general indication of future development and land use patterns.

C. Drainage.

There are several hundred streams of varying flow in the region, tributary to both the free-flowing and estuary portions of the Potomac and Patuxent rivers. A large number of these streams are located in older residential or newlydeveloping areas. Figure 3 shows the metropolitan region, its streams, basins and some of its major jurisdictional boundaries.

D. Sewerage.

The urban area is served by a separate sanitary sewer system with the exception of 14,000 acres in the District of Columbia and 650 acres in Alexandria which are served by combined sewer systems. Further, approximately 7 to 8 percent of the population of the metropolitan Washington area is served by on-site (e.g., septic tank) systems.

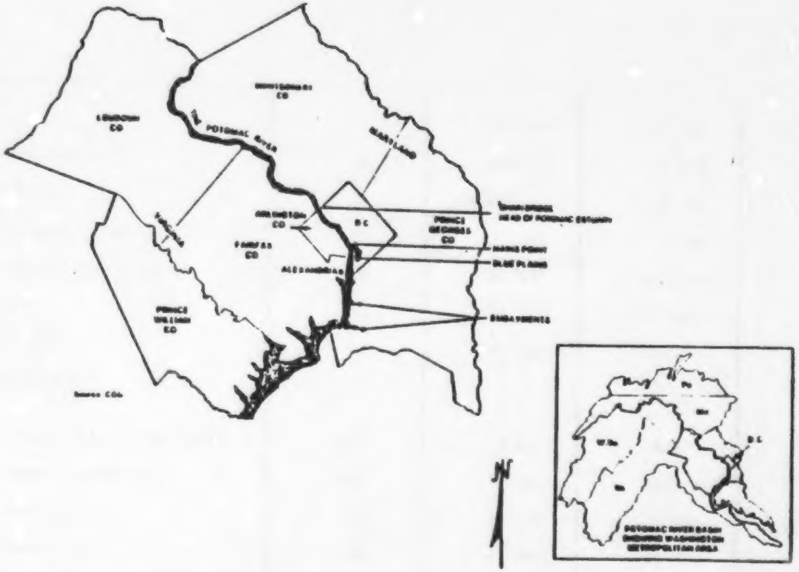


Figure 1. The Washington Metropolitan Area and Potomac River Basin

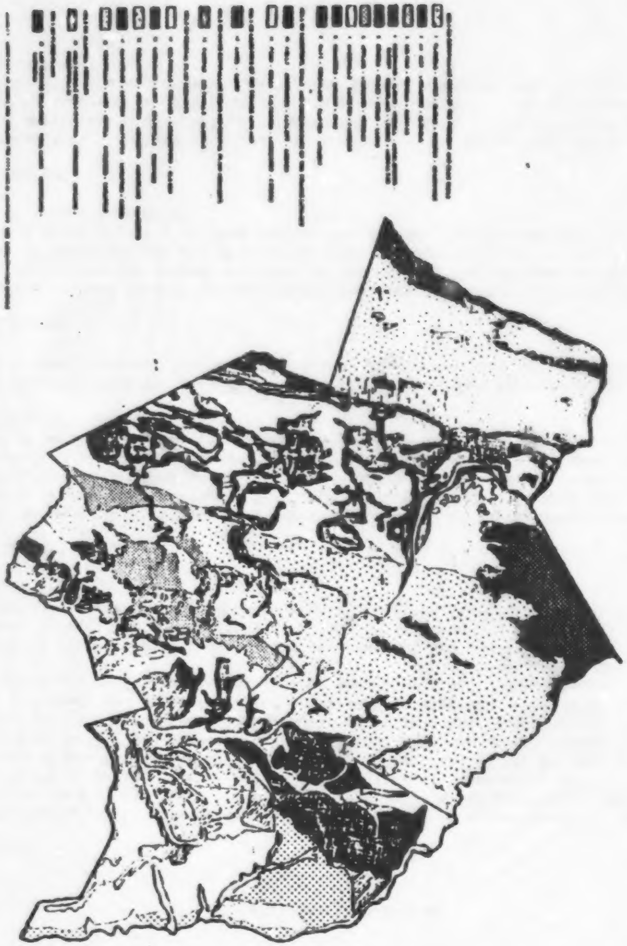


Figure 2. Generalized Soils of Metropolitan Washington

TABLE 1. LAND COVER IN THE WASHINGTON METROPOLITAN AREA

	Estimated Total Percent Imperviousness	Existing (1977) Land Cover in Acres	Projected (200) Land Cover in Acres
Urban/Suburban Areas			
Low-density single family	6%	37,615	100,885
Medium-density single family	25%	137,643	206,880
Townhouse/garden apartment	40%	14,689	17,905
Hi-Rise Residential	70%	28,316	30,391
Institutional	60%	43,580	48,332
Industrial	70%	15,011	23,642
Suburban Commercial	90%	39,671	48,029
Central Business District	95%	3,575	6,133
Rural Areas			
Forest	1%	512,585	436,935
Idle	1%	311,263	271,982
Cropland (Min. till)	1%	61,732	54,323
Cropland (Conv. till)	1%	25,933	22,743
Pasture	1%	206,442	185,176
Tended Areas	1%	68,583	53,083
		1,506,641	1,506,641

Figure 3. Major Washington Area Watersheds

Reproduced from best available copy.

PROJECT AREA

I. Catchment Name - DC1, Catchment 001, Stratton Woods, Roadside Swale, BMP

A. Area - 8.461 acres.

B. Population - No data.

C. Drainage - This catchment has a representative slope of 84.5 feet/mile, 100% served with swales and ditches. The drainage channels approximate a 95.0 feet/mile slope, and extend 1890 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

E. Land Use

8.46 acres is 0.5 to 2 dwelling units per acre urban residential

II. Catchment Name - DC1, Catchment 002, Dufief, Roadside Swale BMP

A. Area - 11.84 acres.

B. Population - No data.

C. Drainage - This catchment has a representative slope of 449.8 feet/mile, 100% served with swales and ditches. The drainage channels approximate a 343.2 feet/mile slope, and extend 450 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 0.78 lane miles of 12 foot wide equivalent lanes.

E. Land Use

11.84 acres of 0.5 to 2 dwelling units per acre urban residential

III. Catchment Name - DC1, Catchment 103, Westleigh Retention Pond (wet) Inflow BMP

A. Area - 40.952 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 195.4 feet/mile, 83.7% served with curbs and gutters and 16.30% served by no sewers. The drainage channels approximate a 127.25 feet/mile slope, and extend 1800 feet.

D. Sewerage - Drainage area of the catchment is 83.7% separate storm sewers and 16.30% no sewers.

Streets consist of 3.26 lane miles of 12-foot wide equivalent lanes. Curbs consist of 2.58 curb miles.

E. Land Use

37.96 acres is 0.5 to 2 dwelling units per acre urban residential.

2.94 acres is Urban Parkland or Open Space.

IV. Catchment Name - DC1, Catchment 004, Fairidge Roadside Swale BMP

A. Area - 18.77 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 227 feet/ mile, 4[illegible]7% served with curbs and gutters and 50.83% served with swales and ditches. The storm sewers approximate a 190 feet/mile slope, and extend 375 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 2.24 lane miles of 12 foot wide equivalent lanes.

E. Lane Use

16.54 acres is 2.5 to 8 dwelling units per acre urban residential

2.24 acres is Urban Institutional

V. Catchment Name - DC1 Catchment, Burke Ponds

A. Area - 18.3 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 230 feet/mile, 100% served with curbs and gutters. The drainage channel approximate a 220 feet/mile slope, and extend 1260 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Curbs consist of 1.52 curb miles.

E. Land Use

18.3 acres is 2.5 to 8 dwelling units per acre urban residential

VI. Catchment Name - DC1, Catchment 106, Stedwick Detention (dry) BMP

A. Area - 24.44 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 248.2 feet/mile, 79.67% served with curbs and gutters and 20.33% served by no sewers. The drainage channels approximate a 227 feet/mile slope, and extend 1000 feet.

D. Sewerage - Drainage area of the catchment is 79.67% separate storm sewers, and 20.33% no sewers.

Streets consist of 2.96 lane miles of 12 foot wide equivalent lanes. Curbs consist of 1.99 curb miles.

E. Land Use

0.57 acres is 0.5 to 2 dwelling units per acre urban residential

20.70 acres is 2.5 to 8 dwelling units per acre urban residential

6.17 acres is Urban Institutional

VII. Catchment Name - DC1, Catchment 107, Lake Ridge Detention Pond (dry) BMP

A. Area - 68.3 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 420 feet/mile, 68.26% served with curbs and gutters and 31.74% served with no sewers. The storm sewers approximate a 164 feet/mile slope, and extend 2220 feet.

D. Sewerage - Drainage area of the catchment is 68.26% separate storm sewers, and 31.74% no sewers

Streets consist of 11.56 lane miles of 12 foot wide equivalent lanes. Curbs consist of 6.10 curb miles.

E. Lane Use

Not available

VIII. Catchment Name - DC 1, Catchment 008, Dandridge Infiltration Trench BMP

A. Area - 1.96 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 190.1 feet/mile, 93.87% served with curbs and gutters and 6.12% served with swales and ditches. The storm sewers approximate a 113 feet/mile slope, and extend 540 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 0.27 lane miles of 12 foot wide equivalent lanes. Curbs consist of 0.13 curb miles.

E. Land Use

1.96 acres is greater than 8 dwelling units per acre urban residential

IX. Catchment Name - DC1, Catchment 009, Rockville City Center Porous Pavement BMP

A. Area - 4.2 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 135 feet/mile, 74.3% served with curbs and gutters and 25.7% served with no sewers. The storm sewers approximate a 135 feet/mile slope, and extend 390 feet.

D. Sewerage - Drainage area of the catchment is 74.3% separate storm sewers, and 25.7% is no sewers.

Streets consist of 1.82 lane miles of 12 foot wide equivalent lanes. Curbs consist of 0.25 curb miles.

E. Land Use

3.12 acres is urban institutional

1.08 acres is urban parkland or open space.

X. Catchment Name - DC1, Catchment 011, Burke Village Shopping Center Infiltration Trench BMP

A. Area - 4.5 acres

B. Population - No data

C. Drainage - This catchment has a representative slope of 85 feet/mile, 82% served with curbs and gutters and 18% served with no sewer. The storm sewers approximate a 30.6 feet/mile slope, and extend 585 feet.

D. Sewerage - Drainage area of the catchment is 82% separate storm sewers, and 18% no sewers.

Streets consist of 2.14 lane miles of 12 foot wide equivalent lanes. Curbs consist of 0.36 curb miles.

E. Land Use

3.69 acres is urban commercial shopping center, 0.81 acres is urban parkland or open space.

PROBLEM

A. Local definition (government)

In 1975, the Water Resources Planning Board (WRPB) of the Metropolitan Washington Council of Governments (COG) was given broad responsibilities and funding support to conduct areawide waste treatment management planning in the Washington metropolitan area pursuant to Section 208 of the Federal Water Pollution Control Act of 1972. In accordance with its mandated responsibilities, the WRPB adopted an initial 208 Waste Treatment Management Plan for the Washington area in June 1978. The Plan was subsequently approved by Washington area jurisdictions and is currently under review by State certifying agencies.

As a starting point for developing an understanding of pollutant sources and impacts affecting Washington area waterways, a water quality assessment was conducted as part of the initial 208 plan. This assessment identified the following general conditions.

- The Potomac estuary experiences periodically excessive algal concentrations and occasional contraventions of dissolved oxygen standards during summer periods of low fresh water inflow and high water temperature.
- Ther is no longer a diversified system of bottom life in the upper Potomac estuary. Nearly all rooted aquatic plants are gone from the estuarial shallows of the Potomac and Anacostia rivers.
- The recreational and commercial value of acquatic life within or dependent upon Potomac and Patuxent River waters has generally declined due to habitat descruction and water quality degradation.
- Few streams in the more urbanized portions of the Washington metropolitan area consistently meet bacterial standards for safe water contact recreation.
- The recreational and aesthetic value of many of the region's stream valley has decreased due to stream channel destruction resulting from uncontrolle storm runoff in urbanizing areas. This has also resulted in declines in the diversity and range of acquatic and water associated species inhabitin these small streams.
- Sedimentation from excessive upstream erosion is reducing the storage capacity of the Occoquan reservoir -- a major water supply source for Northern Virginia. Periodically high suspended solids loads in the Potomac River has also resulted in higher water treatment costs for the Washington Suburban Sanitary Commission at its Potomac filtration plant.

- As the Washington area has developed, related increases in the amount of land surface made impervious to rainfall have increased stormwater runoff pollutant loads and freshwater flows to downstream areas in periods immediately following storm events. The combination of increased freshwater flows from runoff, and increased sediment, nutrient, and bacterial loads being swept down into the Potomac and Patuxent estuaries appear to have reduced available commercial seafood harvesting areas, reduced fish spawning and nursery grounds and stimulated excessive plant and algal growth. Eutrophic levels of algae production is an especially visible problem at the Occoquan Reservoir.

B. Local perception (public awareness)

The public participation program will provide the opportunity to determine the public perception of water resources problems.

PROJECT DESCRIPTION

A. Major Objective.

The Washington Metropolitan Area's Urban Runoff Demonstration Project is being undertaken as one of 28 projects sponsored by EPA in various urban areas throughout the country as part of its Nationwide Urban Runoff Program (NURP). The project will provide information on urban nonpoint source loadings and potential control measure effectiveness needed by EPA in its national assessment or urban runoff problems and potential controls. It will also develop local field data needed to help assess the impacts of nonpoint loadings in Washington area waters and to quantify the costs and effectiveness of potential control measures. This work is critical to the identification and implementation of water quality management strategies that are based on a full understanding of interactive point/nonpoint source loading impacts on the region's waters and the potential control tradeoffs available for meeting clean water goals in the most cost-effective manner.

Individual tasks being executed under this project have been designed to build upon the land use/runoff relationships and Best Management Practice (BMP) pollutant trap efficiency and cost information originally developed for the Washington, D.C. region as part of the Metropolitan Washington Water Resources Planning Board's (WRPB) initial 208 planning effort.

The specific and interrelated tasks being carried out in this project will:

- Document, through monitoring and analysis, the costs and effectiveness of alternative Best Management Practices (BMPs) for nonpoint pollution control.

  Related tasks will associate BMP effectiveness with sediment particle size (for detention controls) and soil absorption characteristics (for infiltration controls).

- Refine atmospheric loading estimates and identify air/water quality management interfaces and possible regional variations in air quality that should be accounted for in the local application of runoff data to specific geographic areas.

- Demonstrate the detailed application of land use/runoff relationships to identify nonpoint source management program alternatives in two prototype local watersheds selected for further study in the region's initial 208 planning effort.

- Refine existing land use/runoff loading estimates in central business district areas which have very high levels of imperviousness and on-site activity.

- Identify the bioavailability of phosphorus loads in urban runoff and the presence of other toxic substances specified in EPA's list of pollutants.

- Identify maintenance and captured pollutant disposal guidelines for urban BMPs having potential application in the Washington area.

In addition, local technical liaison and public participation activities, undertaken as part of overall project execution, are being used to further refine and develop local understandings of nonpoint pollution problems, demonstrate the types of measures currently available to control these problems, and otherwise encourage the participation of local jurisdictions and affected interest groups in the implementation of detailed planning and nonpoint source management activities that may be needed to meet area water quality goals and standards.

All of these activties are needed to develop an adequate understanding of the overall significance of nonpoint loadings and the most cost-effective means available for their control. Without these analyses and associated demonstration of local data applications, it would be most difficult to gain any meaningful degree of local support and participation in implementing those nonpoint management programs that may be needed to protect certain area waters. Final task outputs will also provide EPA with state-of-the-art planning and management tools that will be helpful in the evaluation of other urban nonpoint pollution problems and solutions from the broader perspective of national needs that EPA is addressing through its Nationwide Urban Runoff Program.

B. Methodologies.

The Washington, D.C. NURP project will substantially refine and expand upon the preliminary nonpoint source data base collected during the region's initial 208 water quality planning effort. As part of its initial activities as the designated agency for areawide waste treatment planning in the Washington region -- the Metropolitan Washington Water Resources Planning Board (WRPB) sponsored several field studies to develop basic data needed to identify the major sources and magnitude of area nonpoint pollution contributions and to evaluate the need and options available for nonpoint control. These studies produced estimates of land use/runoff relationships from 11 representative land uses (7 of which were urban/suburban in nature), and Best Management Practices (BMP) pollutant removal efficiency and cost information primarily directed toward BMP applications in urban and developing land uses areas.

Conducted for COG by the Northern Virginia Planning District Commission (NVDPDC) and VPI & SU's Department of Engineering, the land use/runoff study analyzed rainfall and runoff data from over 300 site/storms collected between June 1976 and May 1977 at 21 small watersheds in Northern Virginia. Each composite, the monitored sites represented a mix of the residential, urban and rural land uses typically found in the Washington, D.C area.

More recent studies by the Council of Governments have been directed at assessing the total annual pollutant loading (BOD, N, P) reaching the upper 50 miles of the

Potomac Estuary, by source, and considering both loads delivered by watersheds within the metropolitan region and pollutant loadings originating from the Upper Potomac Basin above the Washington, D.C. area. Using the NVPDC land/runoff relationships previously cited, nonpoint loadings from the region's 42 major watersheds were assessed based on simulations of current (1977) and forecasted (2000) average annual total and unit area nonpoint loads for average rainfall year and according to existing and forecasted land use patterns. Regional versus upper Potomac Basin loading comparisons were developed based on an analysis of US EPA and USGS data taken at Chain Bridge (at the head of the Potomac Estuary) during the late 1970's. Point source loadings were considered based on all permitted discharges to the Upper Estuary and its direct tributaries below Chain Bridge. Projected point source discharges were calculated to reflect implementation, over time, of NPDES discharge permits.

Study Findings

These initial 208-related studies resulted in the following conclusions regarding urban nonpoint pollution, its impact and control in the Washington, D.C. area:

1. The concentration of pollutant loads in runoff from urban sites was significantly higher than runoff from rural/agricultural sites on a per acre basis.

2. Urban runoff contained significant loadings of BOD, nitrogen and phosphorus on a per acre loading basis. Runoff rate, volume and pollutant loadings increased as land area increased in impervious cover (see Table 2).

3. Urban areas with a high percentage of impervious land cover generally shows significant "first flush" effects for certain pollutants.

4. Local stormwater runoff loadings represented roughly one-half the current total annual pollutant loading of BOD, N and P, particularly as point source discharges are brought under control.

5. Local runoff represented approximately 20 percent of the total pollution load at Chain Bridge. A majority of the load originated from sources (primarily nonpoint) upstream of the Washington, D.C. area.

6. Local runoff and upstream nonpoint loadings, if controlled, would far exceed future nonpoint source loadings on an average annual basis (Figure 4).

7. Nonpoint loads from stormwater runoff and combined sewer overflow loads are extremely transient and variable. Both respond directly to runoff produced by precipitation and snow-melt. The generation of nonpoint pollutants ranges from nearly no contributions at all during dry periods to the largest and most important source of pollutants during major runoff events. Similarly, combined sewer overflows typically do not occur unless some type of runoff is generated, but overflows represent the most severe form of localized pollution when they do occur.

TABLE 2. AVERAGE ANNUAL SURFACE RUNOFF SIMULATED FOR URBAN AND RURAL LANS BY SOIL TEXTURE

Land Use	Percent Impervious	Clay Loam	Clay Loam With Pan	Silt Loam	Silt Loam With Pan	Sandy Loam	Sandy Loam With Pan	Loam	Undifferentiated Soil
Estate Single Family	3	6.1	9.1	4.0	6.0	1.3	1.9	3.6	
Low Density Single Family	12	9.2	11.8	7.2	9.0	4.4	5.0	6.7	
Medium Density Single Family	25	12.9	15.1	11.0	12.7	8.8	9.3	10.7	
Townhouse/Garden	45	18.5	20.2	17.7	18.4	15.5	15.9	16.9	
Hi-Rise Residential	70	25.8	27.0	25.3	25.7	24.0	24.2	24.8	
Institutional	35	15.7	17.2	15.7	15.5	12.2	12.6	13.8	
Forest	1	4.4	7.0	2.7	4.2	0.5	0.9	2.3	
Idle	1	6.0	8.9	3.8	5.8	0.7	1.3	3.2	
Minimum Tillage	1	6.6	9.4	4.1	6.2	0.8	1.5	3.6	
Conventional Tillage	1	6.9	9.8	4.4	6.6	0.9	1.6	3.8	
Pasture	1	7.3	10.1	4.7	6.9	1.0	1.6	4.1	
Tended Grass	7	6.1	9.1	4.0	6.0	1.3	1.9	3.6	
Industrial	75								20.0
Suburban Commercial	90								32.7
CBD	95								34.2

NOTE: Surface Runoff was simulted with EPA's Nonpoint Sources (NPS) Model using a continuous rainfall record (NWS raingage at National Airport) for calendar year 1967. Total rainfall for the year was 38.14 inches. Includes only surface runoff from pervious and impervious areas and does not include interflow and baseflow.

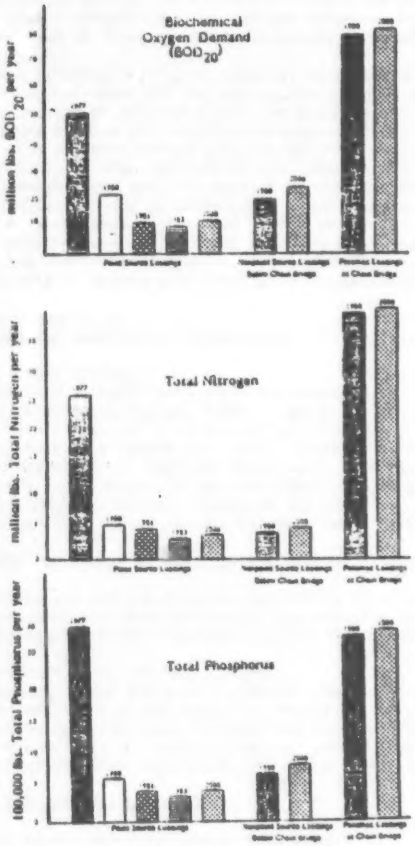


Figure 4. Average Annual Pollutant Loads

8. Uncontrolled urban stormwater runoff volumes posed a threat to stable streambed habitats.

9. Application of certain BMPs appeared to be feasible methods of reducing urban runoff loads, particularly in developing areas of the region. Of these, modification of stormwater management structures to achieve added water quality benefits appeared particularly cost-effective. Habitat protection and trapping of heavy metals were identified as additional benefits provided by certain BMPs. Available data were incorporated into the 1980 Supplement to the region's 208 Water Quality Management Plan.

The following is a summary of task objectives and methodologies:

Task 1. BMP EFFECTIVENESS STUDIES

Runoff inflows and outflows of certain BMPs are being monitored to determine mine pollutant removal efficiencies for different BMPs having potential application in the Washington metropolitan area. BMP efficiency data will be used by local and regional agencies to:

- Address local technical and politcal concerns about the effectiveness of typical nonpoint pollution control measures specified in the initial 208 plan and develop information on the efficiency of local BMPs that is equivalent in detail to the "urban land use-nonpoint pollution" relationships produced by the initial 208 planning study. The BMP efficiency data will be used by local and regional agencies to evaluate nonpoint pollution management strategies for the region's watersheds.

- Refine the region's "urban land use/nonpoint pollution" relationships, produced in the initial 208 planning effort, by collecting and analyzing nonpoint pollution loading data from new monitoring sites under various meteorologic conditions.

- Refine the region's 208 "desktop" nonpoint source and BMP assessment models to enhance applications by local public works and land use planning staffs using the BMP efficiency and nonpoint pollution loading relationships cited above.

- Refine the region's 208 "computer-based" planning models to enhance applications by regional planning agencies involved in water quality management using the BMP efficiency and nonpoint pollution loading relationships.

- Actively involve representatives from the home building industry in the evaluation of BMPs that are being considered for the region's urban areas.

Task 2. AMORTIZED/UNIT COST DATA ON BMP CAPITAL MAINTENANCE AND OPERATING COSTS

Itemized unit cost information is being developed for BMPs used throughout the Metropolitan Washington area. This information will allow for projection of anticipated capital costs of BMPs as well as projections of manpower and equipment expenditures required to maintain BMPs in proper operating condition. Data will be amortized and reviewed with other BMP test results in determining cost-effectiveness of the various BMP alternatives. Operating, maintenance, and pollutant disposal guidelines that are necessary to insure the continued effective operation of these structures will also be developed.

Task 3. SCAN OF 128 PRIORITY POLLUTANTS

While there is strong evidence indicating that storm runoff represents a major contribution of contaminants to acquatic systems, the majority of work in this area has concentrated on traditional sanitary and chemical parameters. To assist in its nationwide assessment of the presence, severity, and sources of 128 priority pollutants, EPA has requested that a limited scan of priority pollutants in runoff be included as part of the NURP project.

Runoff from representative urban land uses (including a central business district, an industrial site, suburban shopping center, and a medium density residential area is being sampled for the 128 priority pollutants identified by EPA.

Task 4. REFINEMENTS OF RUNOFF DATA IN CENTRAL BUSINESS DISTRICT (CBD) AREAS

Several years ago, as part of its overall Combined Sewer Overflow Study, the D.C. Department of Environmental Services installed and monitored the quality of storm runoff from two sampling stations in the Washington area's CBD. At COG's suggestion, the samples collected and sampling methodology were patterned after the NVPDC/VPI&SU study to provide comparable data. Under this task, NVPDC is analyzing the sampling data collected to refine the original NVPDC land use/runoff relationships to specifically reflect CBD areas. (NVPDC's original runoff studies for the WRPB developed relationships for highly impervious areas, but they were more suburban in nature than the CBD.)

Task 5. MONITORING AND ANAYLSIS OF ATMOSPHERIC SOURCE CONTRIBUTION TO URBAN NONPOINT SOURCE LOADS

Initial 208 field work indicated that significant percentages of total nutrient and COD loadings and lesser proportions of other constituents observed in runoff are delivered by precipitation rather than washed off the land surface. More extensive analysis of locational differences in air quality was needed to determine if they were substantial enough to necessitate further refinements of the land use/runoff relationships when they are applied to specific parts of the Washington area. Similarly, a better understanding of the components and sources of atmospheric loads was thought necessary to identify the most appropriate control techniques and interfaces between air and water quality management strategies. As an example, data was lacking on the composition of airborne particulates, their source, dispersion characteristics, and the ultimate manner in which they became entrained in runoff (through wetfall or dustfall accumulation on the land).

This task is attempting to quantify the contribution of atmospheric sources to runoff pollutant loads; consider how air-related sources should be factored into existing land use/runoff quality relationships; assess the relative importance of

atmospheric loads delivered by rainout, washout and dryfall; determine the influence of seasonal and rainfall variations on atmospheric loads; assist in identifying and quantifying possible multiple water and air quality benefits and limitations associated with certain control techniques such as street sweeping; and assist COG's air quality management efforts by providing a greater understanding of fugitive dust sources and possible controls.

The task involves the analysis of hi-vol filter data from eight selected state and local air quality monitoring stations and the establishment and analysis of other data from four wetfall/dryfall sampling sites that were constructed with NURP funding.

Task 6. CONDUCT CRITICAL WATERSHED SAMPLING AND MODEL RUNS TO APPLY RUNOFF RELATIONSHIPS, REFINE DATA TRANSFERABILITY, AND IDENTIFY NPS MANAGEMENT OPTIONS

The land use/runoff relationships developed in initial 208 planning activities were based upon intensive sampling of small watersheds of homogeneous land use in Northern Virginia. Land uses monitored were typical of those found in other parts of the Washington area in terms of kinds of site activity, ranges of imperviousness, and underlying soil conditions. As such, they are quite suitable for developing preliminary estimates of overall regional nonpoint pollutant loads and relative watershed contributions to these loads. However, concerns have been expressed that more detailed demonstrations of runoff data transferability are needed before such relationships are applied to more precisely defined water quality management options and programs that may be needed for specific watersheds.

A transferability analysis of this nature was conducted as part of the Occoquan comprehensive watershed study for the WRPB. In this study, a hydrologic and water quality model was set up and runoff pollutant loads were estimated for large mixed use drainage areas using the described land use/ runoff relationships. These model outputs favorably compared with observed monitoring data once appropriate refinements were made to reflect in-stream process effects on runoff loads. However, additional activity involving hydrologic modeling in conjunction with water quality sampling and analysis was believed needed in other watersheds of the metropolitan area to further demonstrate runoff data applications in different areas having some variation in physiographic and land use characteristics.

The Seneca Creek and Piscataway Creek Watersheds in Maryland were selected as prototype watersheds to further demonstrate to area local jurisdictions the application of metropolitan area land use/runoff relationships in the investigation of nonpoint pollution problems. The watersheds selected have mixed land uses and differing physiographic characteristics, and were selected because of their relative significance for nonpoint source load contributions as determined through the WRPB's critical watershed identification process.

Task 7. PUBLIC PARTICIPATION

This task contains a broad range of public participation activities geared to informing and involving the public in urban runoff evaluations. The objectives of composite subtasks are as follows:

- To inform the public about the problems of urban runoff, the objectives of the NURP project and the nature of the research conducted under NURP.
- To encourage the involvement of a broad range of interested and affected constituencies in BMP evaluation and in the formulation of regional urban runoff policies that may be prompted by NURP project results.

Activities include:

- publication of newsletters and other literature to educate the public on the issues related to urban runoff and NURP studies and objectives.
- preparation of urban runoff exhibits, slides and other audiovisual material
- BMP site tours
- presentations to outside citizen and professional organizations
- COG Public Advisory Committee involvement
- media education
- conference sponsorship

These activities are being timed to parallel the NURP project's technical work and management activities. The initial focus has been on providing information about the urban runoff situation in the Washington area and the objectives and methodology of the NURP project. As the project progresses and data becomes available, more attention will be devoted to surveying the public on issues of BMP acceptability, costs, effectiveness and willingness to pay. A concluding conference in FY '82 is to be sponsored to facilitate discussion between citizens, development interests and public officials on possible policy and implementation approaches to urban runoff control.

C. Monitoring

1. The BMP sites devised in Table 3 and located in Figure 5 monitored, consist of three types of BMP practices as follows:

Source Controls

Programs that are designed to minimize the accumulation of pollutants on the land surface during dry periods between rainfall events, and subdivision site design

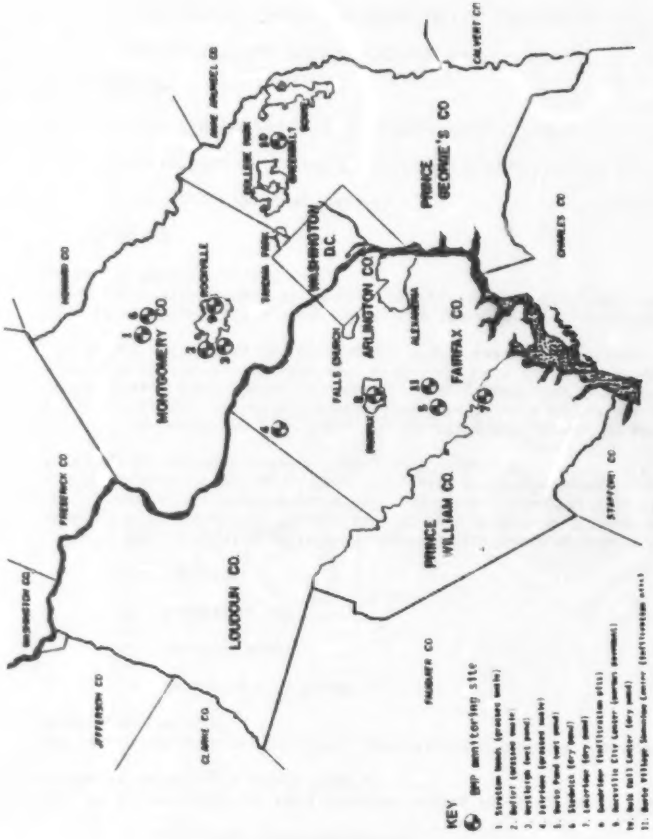


Figure 5. Location of BMP Monitoring Sites

policies that are directed at reducing the potential for generating nonpoint pollutants during storm events. These programs can range from policies that encourage the use of roadside swales and other natural drainage systems in lieu of conventional connected storm drain systems, to reducing roadway pavement widths in order to decrease the total amount of impervious surfaces created through development.

This type of control is being tested at the following NURP sites established during 1980.

- Fairidge (Swale Drainage and Reducted Pavement Width)
- Stratton Woods (Swale Drainage)
- Dufief (Swale Drainage and Reduced Pavement Widths)

Volume Controls

Volume Control BMPs obtain their pollutant removal effectiveness through channeling a specific volume of runoff, containing both dissolved and suspended pollutants, into the soil profile where pollutants are trapped or otherwise degraded by the natural checmical and biological processes that take place in the soil. This type of control is being evaluated at the following sites during this NURP project.

- Dandridge Apartment Complex (Infiltration Pits)
- Burke Village Center Shopping Center (Infiltration Trenches)
- City Center Building (Porous Pavement with underlying stone storage area)

Detention Controls

Detention controls obtains their pollutant removal effectiveness through detaining captured storn runoff for a sufficient period of time to allow suspended pollutants to settle out through the natural sedimentation process. The pollutant removal effectiveness of both "wet ponds" and "dry ponds" were evaluated during 1980. The dry ponds that were evaluated were equipped with modified outlet structures designed to detain storm runoff for a period of 24 hours prior to its release to the receiving waters. The sites being monitored that are equipped with detention controls are:

- Westleigh (Wet Pond)
- Burke Village (Wet Pond)
- Stedwick (Dry Pond)

2. The priority pollutant scan sites are divided into two sets. The first set consists of three paired stations:

1. Fairidge/Stedwick;
2. Dufief/Westleigh; and
3. Burketown Center/Burke Pond.

The close arrangement of these stations allows for sampling to take place at both of the pairs during a single storm event.

The second set of sites consist of a series of individual sampling stations. These sites include:

1. Rockville City Center;
2. Stratton Woods;
3. Dandridge; and
4. Lakeridge.

3. Four wetfall/dryfall (WD) sampling stations have been established as shown in Figure 6 within the COG area as part of this NURP program. These sites are located at the Burke Village Shopping Center in Burke, Virginia, adjacent to the BMP volume control monitoring site, with the other being located at the U.S. Park Service Administrative Building in Southwest Washington, D.C.

4. The eight (8) hi-vol sampling stations established as part of this NURP project represent the widely diversified conditions found within this region. Their spatial distribution throughout the metropolitan area also insures that information gained through this work will contribute to a greater understanding of the impact air quality has on nonpoint source pollution problems.

Five of the stations have been located in the more suburban portions of the region These sites will collect total suspended particulate (TSP) data from the following surburban business districts:

Maryland

Rockville, Montgomery County

Laurel (Laurel Junior H.S.), Prince George's County

Hall (C&P Telephone Co.), Prince George's County

Virginia

Massey Building (Police Station), Fairfax County

Fort Belvoir (South Post Bldge. #247), Fairfax County

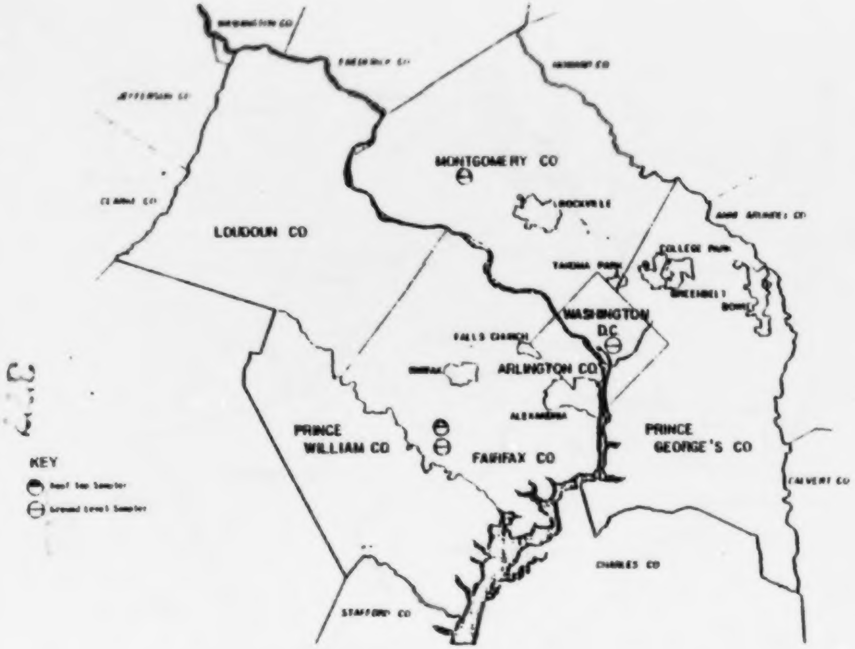


Figure 6. Location of Wetfall/Dryfall Monitoring Sites

The remaining three sites are located in more dense urban areas of the metropolitan region. They are located as follows:

District of Columbia

Catholic University, Northeast D.C.

Hadley Hospital, Southeast D.C.

Virginia

Aurora Hills Community Center, Arlington County

The distribution of these TSP sampling station allows for conclusions to be drawn regarding the variations in air quality that exist betwen the high density business districts and lower density suburban developments. Figure 7 illustrates this regional distribution of TSP Hi-Vol sampling equipment.

5. Two watersheds are being monitored as shown in Figure 8.

Seneca Creek

The Seneca Creek watershed is located in Central Montgomery County, Maryland and drains an area of approximately 82,440 acres. This watershed is located almost completely within the Piedmont Plateau, an area characterized by gently to steeply rolling topography. Elevations within this area range from 850 ft, Mean Sea level Datum (MSL) in the northeastern section to 180 ft MSL at the mouth of Seneca Creek at its confluence with the Potomoac River.

Soils found within the Seneca drainage area are typical of those common to the Piedmont Plateau, having been derived, in part, from the underlying igneous, metamorphic and older sedimentary bedrock. Approximately 45 percent of these soils belong to the Glenelg-Manor and Chester associations. These are well drained silt loam soils that produce moerate to low amounts of runoff in their undisturbed condition. The next largest group of soils (30 percent) are from the Manor-Linganore-Glenelg association. These are also silt loam soils that produce moderate to low amounts of runoff. The last major type of soils (20 percent) found within the area are the Penn and Lewisberry Association that developed from the Triassic sandstone commun to the area. These are silt loam (Penn) and sandy loam (Lewisberry) soils that generate moderate to high amounts of runoff in their undisturbed condition.

At the present time, the Seneca Creek Watershed is primarily rural in character. This situation is expected to change considerably during the next 20 years, however. This transformation will include conversion of extensive areas into single family and other types of residential housing, as well as the more intensive commercial uses. This activity is summarized in Table 4.3.

The results of the NURP critical watershed monitoring will be used to establish and calibrate the Hydrologic Simulation Program-Fortran (HSP-F) continuous simulation water quality model under existing land use conditions. Following the calibration of this model, the project land use changes will be inputed. From

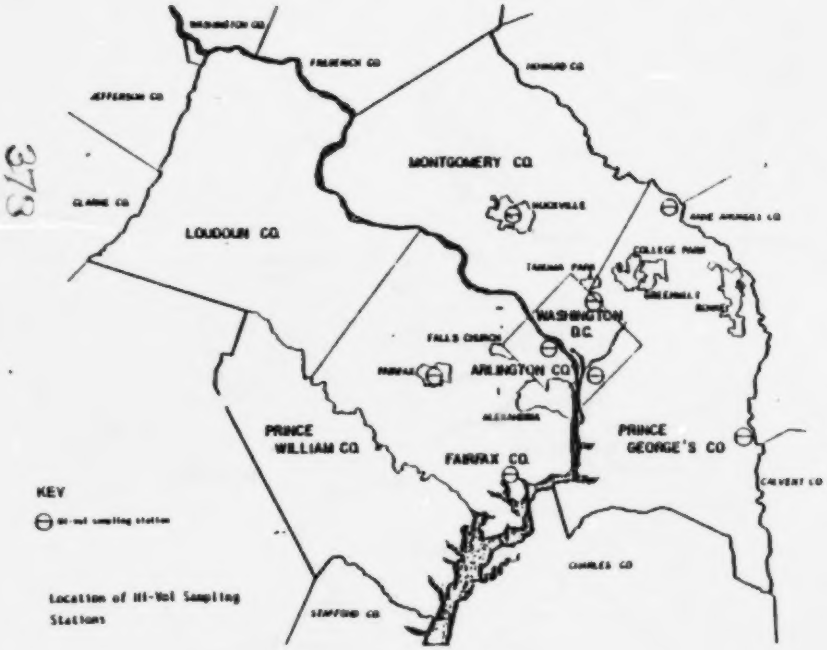


Figure 7. Location of Hi-Vol Sampling Stations

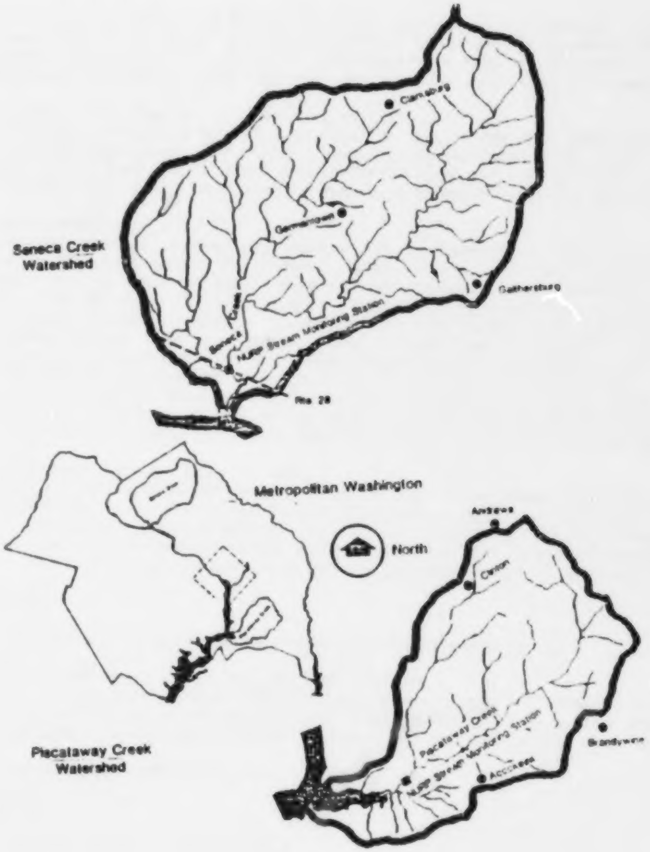


Figure 8. NURP Watershed Study Areas and Monitoring Sites

these changes, the impact of development on water quality within the basin can be evaluated. The results from this study will also allow other jurisdictions with similar physiographic situations to better estimate the impact that extensive changes in land use will have on water quality within their area. In addition this study will provide EPA with a documented working water quality/ land use planning tool.

Piscataway Creek

The Piscataway Creek Watershed is located within the southwestern portion of Prince George's County, Maryland. In contrast to the Seneca area, the Piscataway Watershed is located within the Atlantic Coastal Plain physiographic province. This area is underlain by the unconsolidated deposits of gravel, sand, silt and clay and characterized by gently rolling hills dissected by broad shallow valleys. Elevations within the watershed range from approximately 280 ft MSL in the northeast portion to sea level at the entrance of Piscataway Creek on the Potomac Estuary.

The majority (53 percent) of the soils found within the drainage area are from the Sassafras Croom Association. These are gravelly loam and sandy loam soils that produce low to moderately high amount of runoff in response to rainfall. The second largest group of soils found within the watershed (33 percent) consist of the Beltsville-Leonardtown-Chillum Association. These are silt loam soils that are generally found in the upland portions of the watershed, which because of compact subsoils and substratum layers, generally produce moderately high to high amounts of runoff. The last major group of soils found within the watershed (13 percent) consist of those formed within the tidal marsh and floodplain areas adjacent to the major stream channels of the watershed and the Potomac Estuary. These soils are extremely variable in their characteristics, due to their location, and range from poorly drained to well drained with all subject to some degree of periodic inundation due to flooding.

Even though the Piscataway watershed will not undergo the dramatic changes in urbanization that are expected in the Seneca Watershed, available information indicates that the area will undergo a significant amount of growth during the next 20 years.

D. Equipment

All of the monitoring stations have been designed with equipment being selected to allow maximum flexibility in installation. See Figure 9 for schematic. A brief explanation of the function of each piece of station equipment and its role in the overall station operation follows.

Rain Gaging Equipment

A tipping bucket rain gage with a sensitivity of 0.01" of rainfall was selected for use with voltage accumulator devices. The voltage accumulators count the number of bucket tips (and therefore the amount of rain) and convert the number into a voltage. The voltage created varies from 0-5 vdc. Each increase of 5 mv signifies 0.01" of rainfall. The voltage is constantly maintained, so that whenever a recording device (such as a data logger) queries the accumulator, the total precipitation to the moment may be determined.

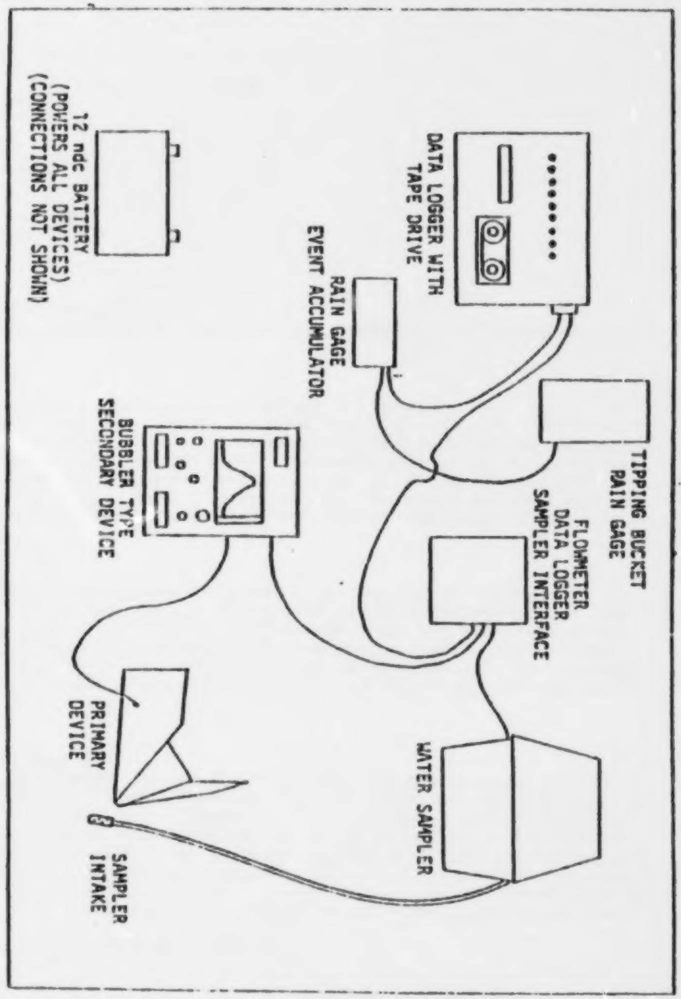

TIPPING BUCKET RAIN GAGE
DATA LOGGER WITH TAPE DRIVE
FLOWMETER DATA LOGGER SAMPLER INTERFACE
WATER SAMPLER
RAIN GAGE EVENT ACCUMULATOR
BUBBLER TYPE SECONDARY DEVICE
12 ndc BATTERY (POWERS ALL DEVICES) (CONNECTIONS NOT SHOWN)
PRIMARY DEVICE
SAMPLER INTAKE

Figure 9. Schematic of NURP Monitoring Station

Primary Flow Measuring Devices

In most cases, a primary flow measuring device was installed at each monitoring location. This primary device is used to facilitate the development of a stage-discharge relationship and consists of some type of flume. The two types of flumes utilized are "Palmer-Bowlus" and Type H." Where possible, the "H" type flume was perferred because of its wide range of flow measurement, ability to function while submerged, and ease of installation.

Secondary Flow Measuring Device

A bubbler-type secondary device was selected for use during this study. The instrument makes use of pressurized gas and a transducer arrangement to measure static head. A microprocessor arrangement then allows for the conversion of static head data directly into flow rate by using the stage-discharge relationship of the primary measuring device. This flowmeter is also the basic controller of the station in that it activates the sampling device at predetermined equal increments of total flow. In addition, the device outputs a 4-20 ma analog signal proportional to the flowrate. At times of sampler activation, the flowmeter also momentarily activates the data logger, which then scans all the appropriate data channels.

Automatic Samplers

The sampling units utilized in this study are all portable, automatically activated 12 vdc battery powered devices. These units are activated by the secondary flow measuring device during periods of flow and are capable of retrieving a 500 ml. sample against a suction lift of 20 feet using a 3/8" hose of 25 ft. long. Each sample is withdrawn at a velocity of 3 feet per second up to 15 ft. of suction head. Each unit has the capability of collecting either discrete of composite samples. These samples are then collected in either a 24 1.0 liter capacity container or a single 15.0 liter polypropylene bottle depending on the needs of the site.

When discrete samplers are collected, each unit can collect up to four (4) samples of equal volume per bottle and distribute a single sample among as many as four (4) bottles. Upon activation, the sample collection unit purges the sample line to prevent contamination both before and after the collection cycle.

Data Logger

A cassette type data logger is attached to the rain gage accumulator and flowmeter. An internal quartz crystal clock allows data from all associated instruments to be recorded on the same time base, thus eliminating the timing error problems that plague the acquisition of synoptic hydrologic data. The logger scans flowmeter and rain gage channels at regularly selected switch intervals and when the sampler is activated.

Power Unit

Each station is powered by a single deep-cycle 12 vdc battery. This unit is changed at a minimum interval of one week, or whenever station power demands make it imperative.

Wetfall/Dryfall Sampling Station Instrumentation

The wetfall/dryfall (WD) sampling stations have been equipped with table mounted, 12 vdc battery operated units that collect material that is deposited under both dry and wet meteorological conditions. This is accomplished by having one of the two sample collection units of equal cross sectional area exposed to the atmosphere. Upon sensing the onset of precipitation, the device automatically closes the dryfall collector to the atmosphere and exposes the wetfall side. Upon sensing the end of precipitation, the sequence is reversed. Samples are then removed to the lab for analysis.

Watershed Monitoring Site Instrumentation

With the exception of the primary flow measuring gages, the equipment deployed at the two critical watershed monitoring sites are identical to those used at the BMP sites. Since both of the critical watershed stations are located at existing USGS flow recording gage sites, it was decided to utilize the inplace controlled stream cross sections as the primary measuring device. While USGS had no objection to allowing installation of this equipment in their gage houses (space permitting), they were unwilling to provide nonagency personnel with direct access to their irreplaceable flow records. This required that the procedure described below be implemented at each site.

Seneca Creek

The secondary recording device is connected directly to the existing USGS stage recording "stilling well." A magnetic reed switch arrangement was then installed on the "Stevens" recorder that allows the water quality sampler to be triggered at each 0.25 ft. interval of rising or falling stage. This procedure produces sequentially collected discrete samples which may then be flow-composited by hand The actual sampler intake hoses are placed in the main stream channel.

Piscataway Creek

Due to space limitations in the existing gage housing, the monitoring equipment at this site is contained in a pad mounted fibergalss protective enclosure adjacent to the USGS structure. The flowmeter bubbler tube is then anchored inside the existing gage house near the USGS datum. The sample uptake probe was then established within the main stream. An Erasable Programmable Read Only Memory (EPROM) is then used to store data from the flowmeter used at the station. Flow weighted composite samples are then collected using this arrangement.

D. Controls

The BMP controls evaluated are source controls, volume controls, and determination controls as described in Table 3.

TABLE 3. FIXED SITE CHARACTERISTICS OF BMP MONITORING SITES

MONITORING SITE		WATERSHED AREA (acres)	AVERAGE DENSITY (DU/ACRE)	[illegible]	[illegible]	BMP CHARACTERISTICS			% OF CATCHMENT AREA WITH SEPARATE STORM SEWERS	% OF CATCHMENT AREA WITH CURB & GUTTERS	% OF CATCHMENT AREA WITH NO SEWERS
						BMP TYPE	STORAGE (cu ft)	OTHER			
						I. LARGE-LOT SINGLE FAMILY RESIDENTIAL					
A. Stratton Woods		8.5	1.8	22.2	16.5	grassed swale	—	—	100	0	0
B. Dufief		11.8	2.2	18.5	13.1	grassed swale	—	—	100	0	0
C. Westleigh	Inflow: Outflow:	40.8 47.9	1.2	21.2 21.7	14.0 13.7	wet pond	191,400	Surface Area: 35,500 sq. ft.	100	83.70	16.30
						II. MEDIUM DENSITY SINGLE FAMILY RESIDENTIAL					
A. Fairidge		18.8	2.8	14.1	21.0	grassed swale	—	—	100	0	0
B. Burke Ponds	Inflow: Outflow:	18.3 27.1	3.0	32.7 30.1	25.1 21.1	wet pond	135,000	Surface Area: 41,400 sq. ft.	100	100	0
						III. TOWNHOUSE/GARDEN APARTMENTS					
A. Stedwick*	Inflow: Outflow:	27.4 [illegible].4	6.1	33.8 30.5	22.1 19.2	dry pond	38,000 (NPS)	5.5' 36" riser	100	79.67	20.33
B. Lakeridge	Inflow: Outflow:	68.3 88.4	9.0	32.6 30.0	27.2 24.0	dry pond	210,000 (10 yr/2hr)	7.5' riser	100	68.26	31.74
C. Danaridge		2.0	56.0	54.4	34.0	infiltration pits	4,060 (void space)	Perforated 6" tile drains	100	100	0
						IV. OFFICE					
A. Rockville City Center		4.2	N/A	69.5	69.5	porous pavement	27,400 (void space)	Perforated 6" drains	100	74.30	25.70
						V. INDUSTRIAL					
A. Bulk Mail Center [c]	Inflow: Outflow:	19.0 20.1	N/A N/A	83.0 78.5	83.0 78.5	dry pond	68,000 (NPS)	1.5' 8" diam. riser	100	*	*
						VI. SHOPPING CENTER					
A. Burke Village Shopping Center		4.5	N/A	79.2	79.2	infiltration pits	11,240 (void space)	—			

*Stedwick has been modified to function as a BMP dry pond (see features affecting the monitoring sites at the end of Section IV for a complete discussion of modifications).

NATIONWIDE URBAN RUNOFF PROGRAM

JONES FALLS URBAN RUNOFF PROJECT
BALTIMORE, MARYLAND

Regional Planning Council

In Association With

Baltimore City
Baltimore County

and the

U. S. Geological Survey

REGION III, EPA

INTRODUCTION

In over 3/5 years, the Baltimore metropolitan area has developed into one of the nation's largest urban centers. This growth, spawned primarily by commercial and industrial interests centered upon maritime activities, has been a major factor of the degradation in quality of the surrounding waters. The region's seven major watersheds provide rapidly flowing freshwater to numerous estuarine embayments which drain into the Chesapeake Bay, the nation's largest estuary. The Bay supports an abundance of finfish and shellfish populations which represent a considerable economic resource to the states of Maryland and Virginia. This delicate ecosystem also represents a major artery of water-borne transportation and a recreational resource of virtually unlimited potential.

Historically, local streams have enjoyed a multitude of uses including drinking water supply, commercial and public fishing, spawning grounds for certain species, boating, swimming, agricultural support, industrial consumption, and the transportation of wastewater discharges. Many of these uses have suffered due to the severe degradation of water quality. Numerous problems have been identified, including the following: extensive land surface and streambank erosion resulting in sediment which fills water supply impoundments and adversely affects aquatic species; enhanced algal propagation with resulting eutrophication in freshwater impoundments and estuarine embayments; and, potentially adverse health effects due to bacterial contamination.

53

Although less than one-third of the region is considered to be urbanized, urban stormwater runoff has been identified as a significant factor in the degradation of local receiving waters. The Jones Falls Watershed, selected because of its representative urban/urbanizing characteristics, provides an excellent case study of urban runoff - its sources, causes, impacts, and cost-effective control measures. More specifically, the Jones Falls Urban Runoff Project (JFURP) is designed to identify and quantify all significant sources of pollutants in the watershed, define the existing water problem(s), and examine selected management practices capable of "cost-effectively" controlling the identified problem(s).

Cooperation among the region's six local jurisdictions in successfully formulating and implementing the Areawide Water Quality Management Program has provided a unique framework for JFURP. Project coordination and technical guidance is vested in the regional forum - the Regional Planning Council (RPC). In light of the fact that the study watershed is located in both Baltimore City and Baltimore County, the participation of these jurisdictions was desirable and has been guaranteed. Past successes in water quality management within the Baltimore Region have been assisted by direct involvement of this nature. The U. S. Geological Survey, an agency with a solid foundation of knowledge in local and national hydrology, was asked to provide technical expertise and resources to the Project; this assistance is provided nationally through a formal coordination plan with the U. S. EPA and locally by cooperative agreement. This cooperative effort has greatly eased the identification of critical issues and priorities through an effective planning and management structure.

PHYSICAL DESCRIPTION

A. Area

The Baltimore metropolitan region is an area of approximately 2,200 square miles. The area is situated in east central Maryland to the west of the Chesapeake Bay and approximately 40 miles northeast of Washington, D. C. The urbanized portion of the region is 589 square miles (26% of total area). The principal, highly developed urban areas are located near the Bay in five of the region's seven major river basins. Much of the older, more intensive urban land use is located in the Patapsco River Basin which also includes the Jones Falls Watershed with an area of approximately 54 square miles. Figure 1 illustrates the Baltimore metropolitan area and the Jones Falls Watershed.

The area lies within the Piedmont and Coastal Plain geologic formations. The region receives, on the average, 45 inches of precipitation a year occurring primarily as rainfall. Precipitation volumes are distributed evenly throughout the year but generally follow a well-defined seasonal pattern: extended, low intensity frontal storms during winter and spring months and short duration, high intensity convective storms.

B. Population

The Baltimore region has a current population of approximately 2.2 million (1980). Two-thirds of the total are located in Baltimore City and County. Development in recent decades denotes a trend from the more established urban areas toward the rural countryside. This trend continues although some reinvestment and relocation back to older urban areas has begun. Of the total developed land in the region, 44% is residential, indicating the level of land consumption for living.

C. Drainage

There are seven major river basins in the region, comprised of hundreds of tributaries. These streams are generally small, shallow, and rapidly flowing, draining a few miles into estuarine embayments. Developed areas of the region include a mixture of natural and man-made storm drainage systems.

D. Sewerage

The urban area is primarily served by separate sanitary and storm sewer systems. Typical storm sewer systems include curbs, gutters, and inlets. A few isolated areas of Baltimore City were developed privately and have a combined sewer system; these were later assumed by the City. Due to the age of the system and rapid growth in the upstream sections, some sanitary sewers have been found to leak and capacity-exceeded problems such as sanitary overflows now occur. There is also evidence of illegal sanitary connections to the storm sewer system. Present 201 studies are directed at correcting these problems.

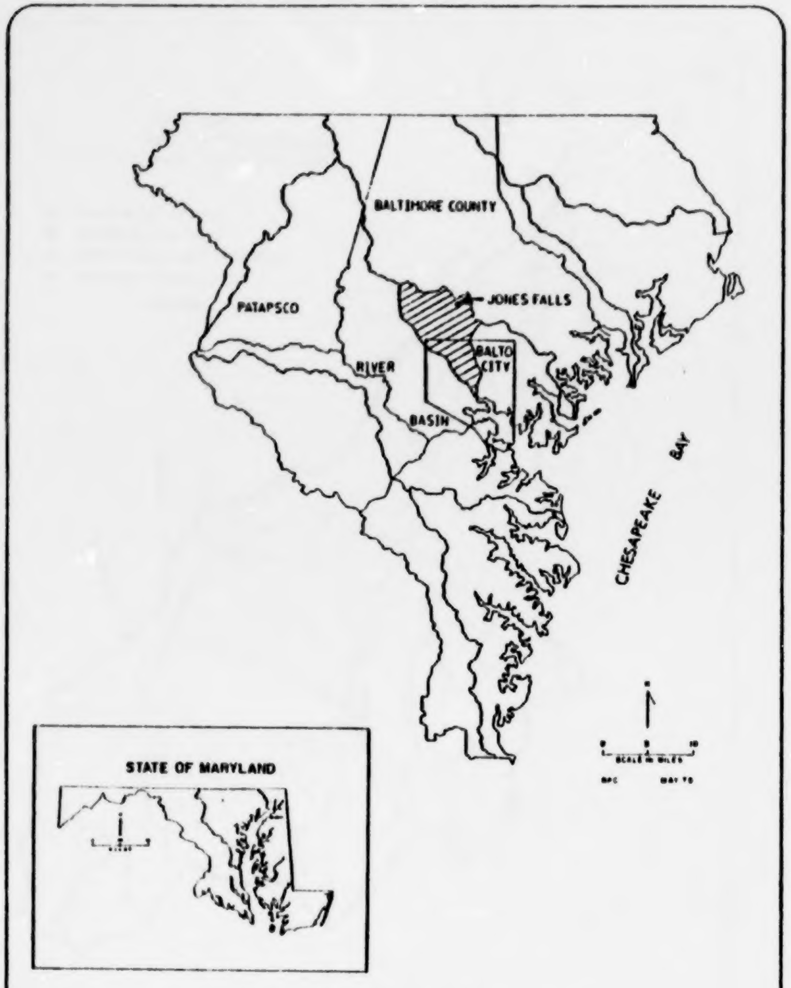


FIGURE 1 - THE BALTIMORE METROPOLITAN AREA
AND JONES FALLS WATERSHED

PROJECT AREA

I. Catchment Name - MD1, Jones Falls Watershed

The Jones Falls Watershed is approximately 54 square miles, and includes all of the listed catchments. Figure 2 provides detailed illustration of the study area.

A. Area - 34,581 acres

B. Population - Not yet compiled

C. Drainage - Subsurface and surface conveyance to the Jones Falls. More specific hydrologic information to be provided later.

D. Sewerage - Not compiled

E.

Land Use	Total Acreage	% of Total Drainage Area
Urban		
- Residential	15,082	44
- Commercial	1,586	5
- Industrial	825	2
- Institutional	1,452	4
- Expressways	461	1
- Cemetary/Recreational	1,955	6
+ Total Urban	21,361	62
Non-urban		
- Agriculture	4,192	12
- Brush/Grass	1,059	3
- Woodlands	7,672	22
- Reservoir	155	.4
- Quarry/Landfill	142	.4
+ Total Non-urban	13,220	38

II. Catchment Name - MD 1, 008, Lake Roland

The Lake Roland catchment area comprises the upper Jones Falls Watershed and is approximately 35 square miles.

A. Area - 22,142 areas

B. Population - Not yet compiled

C. Drainage - Subsurface and surface conveyance to the Jones Falls and Lake Roland. Representative slope of overall drainage basin is 63.32 feet per mile.

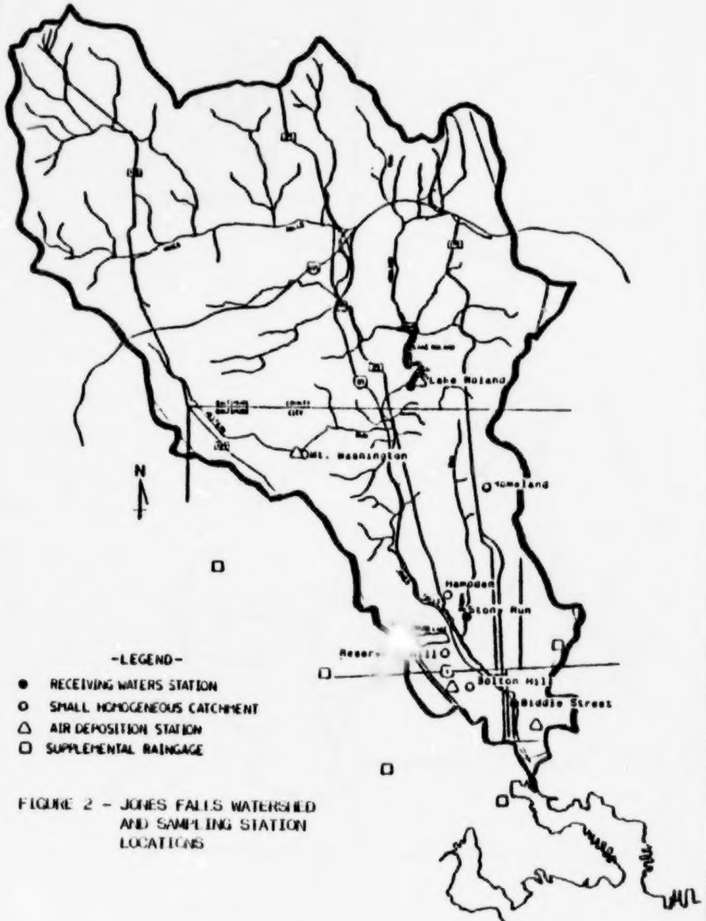


FIGURE 2 - JONES FALLS WATERSHED AND SAMPLING STATION LOCATIONS

D. Sewerage - Not yet compiled

E. Land Use

Land Use	Total Acreage	% of Total Drainage Area
Urban		
- Residential	7,846	36
- Commercial	428	2
- Industrial	212	1
- Institutional	831	4
- Expressways	276	1
- Cemetary/Recreational	843	4
Total urban	10,436	47
Non-urban		
- Agriculture	4,192	119
- Brush/Grass	732	3
- Woodlands	6,575	30
- Reservoir	92	.4
- Quarry/Landfill	115	.5
Total Non-urban	11,706	53

Percent of impervious area not compiled.

III. Catchment Name - MD1, 007, Stony Run

The Stony Run catchment area is a subwatershed within the Jones Falls Watershed and is approximately 3.2 square miles. Two of the small homogeneous catchments, Homeland and Hampden, are located within this area.

A. Area - 2,047 acres

B. Population - Estimate: 51,151 persons based on 12 persons per acre

C. Drainage - Subsurface conveyance to Stony Run, a tributary of the Jones Falls. Representative slope of overall drainage basin is 130.38 feet per mile.

D. Sewerage - Drainage area of catchment is 100% separate storm sewer.

E. Land Use	Total Acreage	% of Total Drainage Area
Urban		
- Residential	1,472	72
- Commercial	95	5
- Industrial	0	0
- Institutional	172	8
- Expressways	0	0
- Cemetary/Recreational	118	6
Total Urban	1,857	91
Non-urban		
- Agriculture	0	0
- Brush/Grass	83	4
- Woodlands	101	5
- Reservoir	6	.3
- Quarry/Landfill	0	0
Total Non-urban	190	9

Percent of impervious area not compiled.

IV. Catchment Name - MD1, 006, Biddle Street

The Biddle Street catchment area includes all of the listed catchment areas and is approximately 53 square miles. This is the lowest point of sample collection in the Jones Falls Watershed.

A. Area - 33,978 acres

B. Population - Not yet compiled

C. Drainage - Subsurface conveyance to the Jones Falls. Representative slope of overall drainage basin is 62.4 feet per mile.

D. Sewerage - Percent of drainage area served by separate storm sewers is not yet compiled.

E. Land Use	Total Acreage	% of Total Drainage Area
Urban		
- Residential	14,797	44
- Commercial	1,425	4
- Industrial	744	2
- Institutional	1,407	4
- Expressways	442	1
- Cemetary/Recreational	1,943	6
Total Urban	20,758	61
Non-urban		
- Agriculture	4,192	12
- Brush/Grass	1,059	3
- Woodlands	7,672	23
- Reservoir	155	.5
- Quarry/Landfill	142	.4
Total Non-urban	13,220	39

Percent of impervious area not compiled.

There are five small homogeneous catchments: Reservoir Hill, Hampden, Mt. Washington, Bolton Hill, and Homeland. These areas are located within the Jones Falls Watershed and range in size from 10 to 23 acres. The areas are predominantly residential.

V. Catchment Name - MD1, 001, Reservoir Hill

A. Area - 10.42 acres

B. Population - 577 persons

C. Drainage - Subsurface conveyance to the Jones Falls. Main channel is 437 feet at a slope of approximately 102.7 feet per mile.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers. 100% is served by curbs and gutters.

E. Land Use

- Residential
  - High (9 more more du/ac) = 10.42 acres, 100% of total drainage area.

VI. Catchment Name - MD1, 002, Hampden

A. Area - 17.02 acres

B. Population - 681 persons

C. Drainage - Subsurface conveyance to the Jones Falls. Main channel is 875 feet at a slope of approximately 274.56 feet per mile.

D. Sewerage - Drainage area of catchment is 100% separate storm sewer. 100% is served by curbs and gutters.

E. Land Use

- Residential

+ High (9 or more du/ac) = 12.27 acres, 72% of total drainage area.

- Commercial = 4.75 acres, 28% of total drainage area

VII. Catchment Name - MD1, 003, Mt. Washington

A. Area - 16.58 acres

B. Population - 195 persons

C. Drainage - Subsurface conveyance to Western Run a tributary of the Jones Falls. Main channel is 825 feet at a slope of approximately 355.2 feet per mile.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers. 87% is served by curbs and gutters and 13% is served by swales and ditches.

E. Land Use

- Residential

+ Medium (3 to 8 du/ac) = 13.91 acres, 84% of total drainage area.

- Recreational = 2.67 acres, 16% of total drainage area.

VIII. Catchment Name - MD1, 004, Bolton Hill

A. Area - 14.02 acres

B. Population - 415 persons

C. Drainage - Subsurface conveyance to the Jones Falls. Main channel is 688 feet at a slope of approximately 53.72 feet per mile.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers. 100% is served by curb and gutter.

E. Land Use

- Residential

+ High (more than 9 du/ac) = 13.28 acres, 95% of total drainage area

- Recreational = .73 acres, 5% of total drainage area.

IX. Catchment Name - MD1, 005, Homeland

A. Area - 23.03 acres

B. Population - 204 persons

C. Drainage - Subsurface conveyance to Stony Run a tributary of the Jones Falls. Main channel is 350 feet at a slope of approximately 181.02 feet per mile.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers. 100% is served by curb and gutter.

E. Land Use

- Residential

+ Low (½ to 2 du/ac) = 23.03 acres, 100% of total drainage area.

PROBLEM

A. Local Definition (Government)

Section 208 of the Federal Water Pollution Control Act Amendments of 1972 addressed areawide waste treatment management planning, designating certain local and regional government agencies to plan for improved water quality while concurrently reviewing environmental, land use and organizational issues related to solving water quality problems in their respective areas. The six member jurisdictions of the Regional Planning Council (RPC), through the Baltimore Region's Areawide Water Quality Management Process, reported that urban runoff was a major contributor of pollutants to local receiving waters. Following Federal guidelines, a water quality management plan was adopted by the six member jurisdictions, establishing an implementation process to prevent, reduce, and eliminate sources of contamination of regional waters.

The 208 Plan identified the Jones Falls as one of the most severely degraded streams in the region. This stream is representative of the variety of water quality conditions found throughout the region. Emanating from springs in Baltimore County, the Jones Falls meanders toward the south into an old, man-made water supply impoundment located near the City/County jurisdictional boundary. Upper watershed streams have been designated by the State of Maryland as suitable for the support of trout population growth and propagation and related food sources. This designation represents the most stringent of the State's four receiving waters classifications, which include the following: contact recreation and aquatic life waters, shellfish harvesting waters; natural trout waters; and, recreational trout waters. In spite of the encroachment of the urban area, slowed somewhat by local government intervention, local fishermen report that certain upper Jones Falls tributaries do indeed support a trout population.

Lake Roland is an almost 60-acre impoundment completed in 1861 to serve as Baltimore's first major water supply reservoir. This lake suffers from a variety of problems, which include the following: exponential sedimentation and the resulting loss of storage capacity; eutrophication; and, violations of state bacterial standards. The Lake Roland Clean Lakes Project, sponsored under Section 314 of the Act, is currently investigating the lake's problems and attempting to identify potential solutions to restore and maintain beneficial uses associated with recreation.

After exiting Lake Roland, the Jones Falls continues to flow southward, passing through Baltimore City into a large conveyance tunnel and finally emptying into Baltimore Harbor, the estuarine section of the Patapsco River. The State has recently reclassified this section of the stream to a Class III receiving water, capable of supporting adult trout for put-and-take fishing. Since 1979, rainbow trout have been stocked in the upper reaches of this section of the stream; results of this effort are not yet apparent.

The section of the Jones Falls below Lake Roland is also the most influenced by urbanization and the associated pollutant sources. These include NPDES discharges from industrial/commercial users, sanitary sewer overflows, illegal connections, and increased runoff volumes due to impervious areas.

To recover and maintain designated beneficial uses, the State has promulgated water quality standards including a range of physical chemical parameters. The two parameters with major violations of state standards are turbidity and bacteria - turbidity being storm-related and bacteria in a range of stream conditions.

Storm wash-off results from selected land uses indicate signficant levels of nonpoint pollution entering the receiving streams in the watershed. The direct impacts upon receiving streams and relative magnitude comparisons to other pollutant sources have not been established. Also, the existing levels of urban housekeeping management practices being implemented by local governments focus upon aesthetic and primary public health objectives rather than water quality. The effectiveness of these non-structural controls aimed at reducing the magnitude of source-related pollutants is not known. The primary question is how effective are current levels of urban housekeeping in pollutant removal in comparison to alternative strategies, and what is the relative cost-effectiveness of the control applications for achievement of water quality objectives.

B. Public Perception (Public Awareness)

The assessment of public perception of water quality benefits and problems in a stream or lake requires careful investigation. In the planning of JFURP, a vigorous public participation strategy was developed in recognition of the fact that there is a wide range of diversity in the "public" and perhaps many perceptions of benefits and problems. JFURP intends to provide guidelines to determine how the public perceives of local water quality problems. In each of the land use categories being examined, public lifestyles and, therefore, public perception and expectations of water quality will be different. For example, citizens in heavily urbanized downtown Baltimore probably will not have an interest in, or awareness of, their impact upon downstream estuaries. Inhabitants of rural areas, on the other hand, may be seriously concerned about their impact upon local bodies of water and interested in assuming an aggressive posture when addressing water quality issues.

In reviewing water quality management strategies, these and other differences must be taken into account. A first step will include citizen surveys in each of the land use areas under scrutiny to determine how they perceive local water quality management programs and what level of control they consider necessary. Moreover, citizens must be informed of the significant economic realities associated with specific management strategies. In the end, public value judgements will be balanced against realities of economics, politics, and technical decisions and limitations.

Examples of efforts inspired by individuals and public and private organizations to revitalize areas in Baltimore adjacent to the Jones Falls and other receiving waters include the following:

1. A massive urban renewal campaign encouraged by the City and private groups to rebuild local communities and the Inner Harbor in the vicinity of the Jones Falls outflow.

2. Strong local community interest in neighborhood "cleanliness" and nearby streams via clean-up campaigns, stream "watchdogs", and other actions.

3. Independent stream monitoring and revitalization programs sponsored by organizations staffed primarily by volunteers.

4. Increased use of various streams and surrounding valleys by community children, joggers, hikers, and other public groups.

5. The development of far-reaching water quality public advisory committees operating in local jurisdictions and at the regional level to encourage citizen awareness and education, and provide for forums for the elucidation of various viewpoints.

In brief, the public awareness of JFURP and the existence of urban runoff is not only desirable, but essential. The public response to questions posed about water quality "problems" in the Jones Falls will be encouraged.

Project findings, conclusions, and resulting technology gained from monitoring and data analysis will be disseminated by reports and a series of technical transfer sessions. These and other actions should provide the basis for future inclusion of urban runoff problem assessment and development of control strategies in the Baltimore region's water quality management activities.

PROJECT DESCRIPTION

A. Major Objectives

There is abundant evidence that the Jones Falls Watershed is plagued by the ravages of nature and the myriad degradations exercised by anthropogenic activities. Identified sources of water quality impairment include the following: urban runoff, sanitary sewer overflows, sediment releases, streambank erosion, upstream pollutant loadings, unsewered areas and illegal storm sewer connections. The review of specific problems, as identified in the "PROBLEM" section of this summary, resulted in the development of JFURP objectives based upon local concerns and the primary objectives stated by EPA. In brief, the JFURP objectives are as follows:

1. Investigate and define water quality contaminants, sources, transport mechanisms, and receiving water impacts in the urbanized Jones Falls Watershed.

2. Quantitatively define the total pollutant contributions of the Jones Falls Watershed to the Baltimore Harbor.

3. Identify and assess the sources and transport mechanisms from a variety of small, relatively homogeneous land uses in a stable urban watershed and determine their comparability with similar areas in the Eastern United States.

4. Determine the efficacy of existing source control management practices and operational implementation strategies in the reduction and/or prevention of water quality degradation.

5. Determine the efficacy of Lake Roland as a water quality/quantity management practice and its role in water resources management, especially for downstream control.

6. Provide information supporting the development of an integrated, cost-effective water quality management program for the urbanized Jones Falls Watershed through the "208" Program.

7. Provide a basis for transfer of project findings to the related technical public and private communities for future stormwater runoff management planning and implementation.

Additional work will include local technical liaison and public participation activities. The combination of efforts should result in a mechanism for balanced decision-making. Data collected throughout the Project should provide an illumination of choices which rest upon scientific evidence. Subsequent clarification of the cost-effectiveness of the control techniques and strategies becomes an input necessary to provide a management structure which includes the considerable realities of economic limitations.

B. Methodology and Associated Monitoring

Deficiencies in knowledge demand that a methodology be developed providing a structure for obtaining the information required to explain the issues confronting decision-makers. With problems and objectives now defined, a range of techniques is selected, designed to reduce the existing state of scientific uncertainty within resource limitations.

Briefly stated, the Project intends to quantify the various inputs to the lower Jones Falls Watershed and assess their impact upon the water quality of the stream and its subsequent output into the Baltimore Harbor. Specific attention will be focused upon the development of an urban nonpoint source data base suitable for use as a planning and management tool in the evaluation of local, regional and national problems and solutions.

Monitoring is a critical facet of the Project, with requirements defined by data needs. JFURP Monitoring is summarized in the following components:

1. The monitoring of quantity and quality of the Jones Falls stream during base-flow (dry weather) conditions.
2. The monitoring of quantity and quality of the Jones Falls during high flow (storm events).
3. The monitoring of quantity and quality of rainfall and runoff during storm events at five selected small homogeneous catchments of predominant land covers in the watershed.
4. Atmospheric deposition quantity and quality monitoring: dryfall and precipitation.
5. The quantity and quality monitoring of sanitary sewer overflows and direct sewer discharges during base-flow and storm conditions.
6. Industrial/commercial NPDES discharge monitoring for load assessment.
7. Collection of stream bottom sediment samples throughout the year to define seasonal conditions.
8. The collection and analysis of street dust and dirt to assist in the evaluation of pollutant source accumulation and non-structural housekeeping management practices.
9. Supplemental rainfall monitoring throughout the watershed.
10. A range of miscellaneous activities designed to support the primary components.

There are varying degrees of dependence between these facets of monitoring: the ultimate goal is, of course, to complement the knowledge gained with a perspective which recognizes the effects of one element upon another. This approach is calculated to provide the input necessary for the definition and implementation of a practicable water quality management strategy.

The monitoring of base-flow and storm conditions in the Jones Falls and of urban runoff at the five small homogeneous catchments relies upon automatic samplers and flowmeters. Base-flow samples are collected biweekly. Storm sampling depends upon the activation of the automated sampling equipment by an associated pressure transducer type recording flowmeter to permit the collection of discrete samples at a number of points along the runoff hydrograph. The flowmeter places an event mark on its strip chart in order to record the time at which each sample is taken.

Flow rates for each monitoring station are derived from the stage measurements recorded by the flowmeters. Natural controls were used to develop stage-discharge relationships wherever possible; artificial controls were installed at other locations. In addition, chemical gaging techniques are being used to verify rating curves in storm events.

The collection of dryfall and wetfall samples is also being performed with automatic equipment. In addition, a continuous recording, tipping-bucket raingage with a sensitivity of 0.01 in. was installed near or within each study area to provide the required rainfall information. Supplemental rainfall data are being supplied by the National Weather Service long-term gages and eight supplemental gages maintained by USGS; these are being used to enhance the data base as well as to check data collected by JFURP equipment.

A combination of automated and manual techniques is being used for other monitoring elements associated with discharges to the Jones Falls. These methods have been outlined by several publications, including the NPDES Compliance Sampling Inspection Manual.

Street dust and dirt samples are collected during daylight hours by a field crew using an industrial wet/dry vacuum cleaner. Subsamples are collected within the small homogeneous catchments by running the vacuum cleaner intake along the street surface from curb-to-curb.

The collection, handling, preservation and analysis of all samples resulting from JFURP activities follow procedures which have been outlined by the U. S. EPA and supplemented by project-developed methodologies.

C. Controls

An important facet of JFURP is the evaluation of certain pollutant control or management practices for removal efficiency, cost-effectiveness, and feasibility of application. The following two practices have been identified for evaluation:

1. An assessment of the efficacy of a total watershed "best urban housekeeping practices" strategy and its comparison to existing practices employed by Baltimore City.
2. Study the efficacy of Lake Roland as a water quality/quantity detention control structure.

The study of urban housekeeping practices (including street, alley, and stormdrain cleaning; animal litter control; and general sanitation) will examine the feasibility of applying these methods in low to high density commercial and residential areas within the Jones Falls Watershed. This element of JFURP is significantly affected by a number of items, including economic restraints and the existing drive toward urban revitalization within Baltimore City. Communities within the city are, for the most part, well-organized and vocal in the protection of local interests. The socio-political aspect of this cannot be neglected: uniformity of solution may not generally apply. Management strategies should attempt to satisfy the needs of the communities with their multiplicity of competing objectives.

The study of Lake Roland and its efficacy as a management practice is being performed in the following manner: the Lake Roland Clean Lake Study, supported by the U. S. EPA Section 314 funds, will gather one year of base-flow and storm event water quality and quantity data. In a co-operative effort, JFURP and the Clean Lakes Study will examine the current condition of Lake Roland and its efficacy as a management practice. JFURP has assumed a secondary posture in the collection and evaluation of information gathered.

D. Progress to Date

The progress of the various aspects of the Project is summarized below:

1. The collection of base-flow and storm event samples occurs regularly at the stream monitoring stations; activities were initiated in October, 1980.

2. The collection of storm event samples occurs regularly at the five small homogeneous catchments; activities were initiated in early 1981.

3. Flow rating curves for all sites are being developed. This task is approximately 75% complete.

4. Dryfall and wetfall samples are collected regularly at JFURP atmospheric deposition stations. This includes the compilation of rainfall data as provided by the continuous recording, tipping-bucket raingages.

5. The monitoring of sanitary sewer overflows occurs regularly in conjunction with stream monitoring events.

6. A strategy for the monitoring of direct sewer discharges awaits field implementation.

7. A strategy for industrial/commercial discharge monitoring awaits implementation.

8. Instream bottom sediment sampling is underway.

9. A strategy for the collection and analysis of street dust and dirt samples has been developed and sampling was initiated in October, 1981.

10. Field sampling associated with the Lake Roland Clean Lakes Project has been completed and a draft final report is nearing completion. JFURP has received raw data collected throughout the study: its review is forthcoming.

As might be expected in any project of this scope, numerous problems were encountered during the first months of work. Base-flow monitoring has proceeded smoothly; the sampling of rainfall events, however, has been less successful. Automated equipment must be used because of the capricious nature of rainfall patterns and limitations in budgeted resources. Unfortunately, experience has proven that automatic equipment is capable of mischief.

The overall project plan of action attempts to correlate all facets of the study in a systematic fashion and, in doing so, admit for the probability of mechanical and operator error. Experience results in the introduction of proper control techniques to assure system reliability and collection of accurate data through a rigid quality assurance program. JFURP has reached a stage where the most prominent work elements continue in an orderly manner toward the achievement of objectives with high quality data results. Analysis of project data proceeds toward the achievement of stated objectives.

NATIONWIDE URBAN RUNOFF PROGRAM

WACCAMAW REGIONAL
PLANNING COMMISSION

MYRTLE BEACH, SC

REGION IV, EPA

INTRODUCTION

The 208 Areawide Water Quality Management Plan for Waccamaw Regional Planning and Development Council (WRPDC) was based upon a comprehensive inventory, analysis and quantification of water pollutant sources within the region. Water quality problems were prioritized and addressed in the 208 plan reports.

One of the recognized water quality problem areas involved stormwater from the City of Myrtle Beach. Stormwater from Myrtle Beach is discharged directly onto the beach or into various swashes which flow across the beach into the Atlantic Ocean. There are more than 280 direct pipe discharges onto the beach within the Myrtle Beach city limits. While some of the small pipe discharges are from swimming pool drains and pool filter backwashes, more than 160 are direct stormwater discharges from streets and property drains. The city of Myrtle Beach felt that these beach discharges adversely affect water quality, beach erosion and beach appearance.

Preliminary sampling of these beach discharges indicated they had high bacterial counts. Based on this sampling, a detailed stormwater runoff study was proposed that would develop the solutions necessary to correct the existing water quality problems which resulted from the urban stormwater runoff. This runoff study was accepted by EPA Headquarters as part of the Nationwide Urban Runoff Program.

PHYSICAL DESCRIPTION

A. Area

The area being studied includes the commercial strip and bathing beaches along the "Grand Strand" area of Myrtle Beach.

B. Population

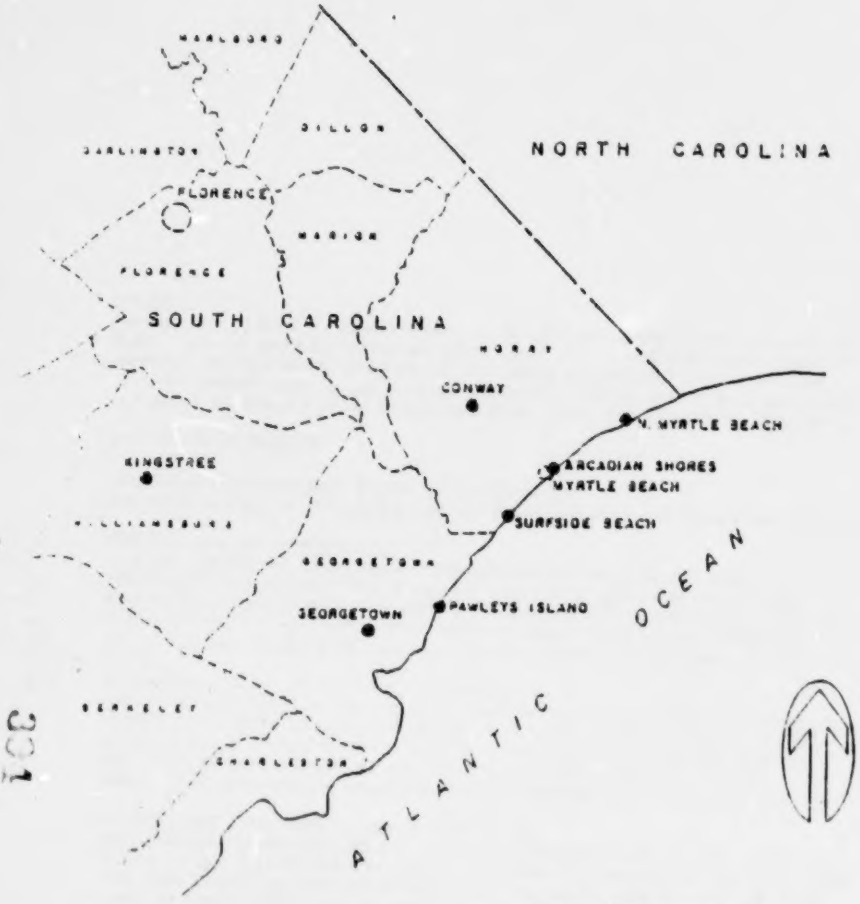
Myrtle Beach and the Grand Strand area entertain over 6,000,000 visitors per year. Myrtle Beach alone hosts up to 250,000 visitors on major holiday weekends. The area's largest industry of course is tourism.

C. Drainage

The drainage consists of pipe systems draining directly to the beach area.

D. Sewerage System

The Myrtle Beach area is served entirely by separate sewer systems.



LOCATION MAP

● COMPARATIVE TOWN LOCATION

PROBLEM

A. Local Definition (Government)

The Waccamaw Regional Planning and Development Council received a grant from the USEPA in June 1975 to prepare an areawide water quality management plan for the Waccamaw region. The Waccamaw Regional 208 Areawide Water Quality Management Plan, completed in 1978, contained strategies for local water quality improvement through integration of various federal pollution abatement requirements-municipal, industrial, residual wastes, stormwater runoff, groundwater pollution abatement-and placed the responsibility for planning and implementing these requirements with regional and local agencies.

The 208 Areawide Water Quality Management Plan was based upon a comprehensive inventory, analysis and quantification of water pollutant sources within the region. Water quality problems were prioritized.

One of the recognized water quality problem areas involved stormwater from the city of Myrtle Beach. Stormwater from Myrtle Beach is discharged directly onto the beach or into various swashes which flow across the beach into the Atlantic Ocean. There are more than 280 direct pipe discharges onto the beach within the Myrtle Beach city limits. While some of the small pipe discharges are from swimming pool drains and pool filter backwashes, more than 160 are direct stormwater discharges from street and property drains. The local government feels that stormwater runoff adversely affects water quality, beach erosion and beach appearance.

A 1972 study by EPA indicated that many of the Myrtle Beach stormwater discharges had high bacterial counts. The discharges were cited by the study as posing a potential health hazard along the extensively developed and utilized beach.

Two stormwater pipes discharging onto the beach were also monitored, sampled and analyzed during the 208 study. The sampling occurred in October 1976. The bacteriological results of the sampling confirmed the initial EPA findings as to the seriousness of bacterial concentrations in the stormwater being discharged onto the beach.

Based on this work, Waccamaw RPDC and South Carolina Department of Health and Environment Control concurred that the Myrtle Beach stormwater runoff was a high priority state problem.

The two levels of government felt that Myrtle Beach's stormwater problem required attention because large quantities of materials contained in the urban runoff enter Withers Swash or flow directly onto the beach and into the ocean waters. They felt that the seriously degraded water quality in the surf has the potential for containing disease causing bacteria that could affect anyone swimming in, using, or eating food obtained from those waters.

The Myrtle Beach area provides the attraction for very extensive tourist trade, which is the prime revenue producing "industry" of the Grand Strand. The local decision makers felt that the water quality problems that they felt existed potentially threatened the source of tourist expenditures in South Carolina.

In addition to the water quality problem, another major area of concern to the local government was the beach erosion. Stormwater runoff from the city of Myrtle Beach causes extensive beach erosion after every significant rainfall. Runoff is collected in the stormwater system and transported to the over 160 pipes discharging directly onto the beach. As the runoff flows from the discharge pipes, it erodes the beach sand and creates pools and gullies across the beach.

These pools and gullies are usually smoothed out to the high tide line by the erosion and deposition action of the tidal cycles. The gullies enable the tides to reach further up the beach to the pipe discharge points. As the sand bank around the discharge pipe dries out after rain storms, the tidal action in the gullies creates further collapse and erosion of the drain line. This erosive action continues as long as stormwater flows across the beach or until the tides have filled in the gullies.

Runoff from the numerous paved parking and terrace areas between the beach and Ocean Boulevard often is not collected by the stormwater system. It flows as sheet runoff across the paved areas and falls directly onto the beach. This sheet runoff contributes to erosion along the remnant of the dune line that still exists so that structural retaining walls are necessary to prevent further loss of soil and property.

The appearance of the beach is also something the local government is concerned about. Over 280 pipes, many corroded, chipped, and supported on make shift wooden braces that extend further across the beach each year as beach erosion continues, are a current feature of Myrtle Beach's prime tourist attraction. Unsightly, stagnant runoff pools on the beach also detract from its appearance.

The local officials are interested in correcting both the stormwater quantity and quality problem that exists in Myrtle Beach.

B. Local Perception

The local population is of course concerned about the stormwater problem if it means losing some of the tourist industry. The local resident population however, is very small compared to the number of tourists that visit the area. The tax base generated by local taxes is nowhere near that needed to finance any cleanup of the problem, if in fact it is determined that one is needed.

PROJECT DESCRIPTION

A. Major Objective

The Myrtle Beach stormwater study was designed to provide Myrtle Beach, Waccamaw RPDC, EPA and South Carolina DHEC with specific information that will enable decisions to be made regarding stormwater runoff related water quality problems. First, the seriousness of water quality problems was to be determined through a sampling program. The second objective of the study was to identify, screen and recommend solutions that would reduce the amount of pollutants entering the surf from stormwater runoff. Preliminary engineering design and cost estimates for the best runoff control alternatives were to be developed and presented. A third objective was to identify, examine the applicability of, and recommend non-structural runoff control measures for implementation by Myrtle Beach and Horry County.

To provide a gauge against which to compare the costs of runoff controls, the study had a fourth element which involved examination of the economic costs to the city and region of taking no action to control runoff. This "no action" alternative projects the impacts to the local economy of a decline in tourist numbers if continued water quality degradation reaches a magnitude where closing the beach after storms might be necessary.

B. Methodologies

Extensive bacterial sampling was performed to gather information on the quality of recreational and other waters within the commercial section of town during dry and wet conditions.

In the beginning of the project all existing direct discharges to the beach were inventoried in an attempt to select primary and secondary sampling sites. It was decided upon that 120 of 160 discharges to the beaches and swashes were to be selected for initial sampling.

The sources of the coliforms were to also be defined. The ratios of fecal coliform to fecal strep were used to determine if the sources were primarily of human or animal origin.

In order to evaluate the water quality of direct beach discharges, pipe streams flowing across the beach, and natural beach pools, established South Carolina water classification standards were used for comparison. However, there are no South Carolina water classifications standards which are applicable to direct beach discharges, pipe streams, or natural beach pools.

C. Monitoring

A total of 289 separate and distinct stormwater pipes discharging directly to the beach inside the Myrtle Beach City limits were identified, located, and inventoried. Based on the inventory, 120 pipes were selected for more intensive sampling. The location of these selected pipes and random sampling stations are shown in the following maps.

The City of Myrtle Beach was divided into six contigious sections according to predominant land use. A brief description of each section is shown in the following table:

Section	Location	Predominate Land Use	Direct Beach Discharge No.
1	North Myrtle Beach City Limits to 69th Ave. North	Open Space	1-12
2	69th Ave. North To Sunset Trail	Mixed Residential and Commercial	13-15
3	Sunset Trail to Hampton Circle	Residential	16-20
4	Hampton Circle to 29th Ave. North	Mixed Residential and Commercial	21-33
5	29th Ave. North to 20th Ave. South	Commercial	34-111
6	20th Ave. South to South Myrtle Beach City Limits	Mixture of Commercial, Residential, and Open Space	112-120

After initial sampling, it was decided that Section 5 would be intensively sampled since this section contained the majority of the commercial section of the city and this was where the tourist population was centered.

Samples were collected from 4 places during wet and dry periods: direct beach discharges, swashes, surf, natural pools. Samples were collected during the storm, 4 hours after a rainfall event and 24 hours after a rainfall event. Samples were also collected during dry weather as a means of comparison. The samples were analyzed for fecal coliform and a selected group of metals.

D. Controls

Alternative control methods, structural and nonstructural, were identified and screened in an effort to select three to five alternatives having cost-effective potential.

The structural and nonstructural control alternatives considered included ocean outfalls, disinfection, collection, transport, and release at selected locations, collection and discharge to the Intracoastal Water Way, use of porous paving and any combination of these measures.

The four basic structural alternatives considered for controlling Myrtle Beach's runoff were: ocean discharges, collection and diversion, disinfection and infiltration.

The evaluation procedures for the alternatives considered hydrology, storm frequency, and engineering economics. A detailed analysis was performed to establish the hydrologic characteristics of each of 25 areas or subbasins that contribute storm runoff to the section 5 portion of Myrtle Beach. This analysis established a methodology for determining peak and total storm flows for rainfall frequencies that would recur on an average of 3 month, 6 months, and 1, 5, 10, and 25 years.

The frequency of the storms was considered. The cost evaluation prepared show that the rankings of alternatives for controlling both the one-year and the 25 year storms are identical.

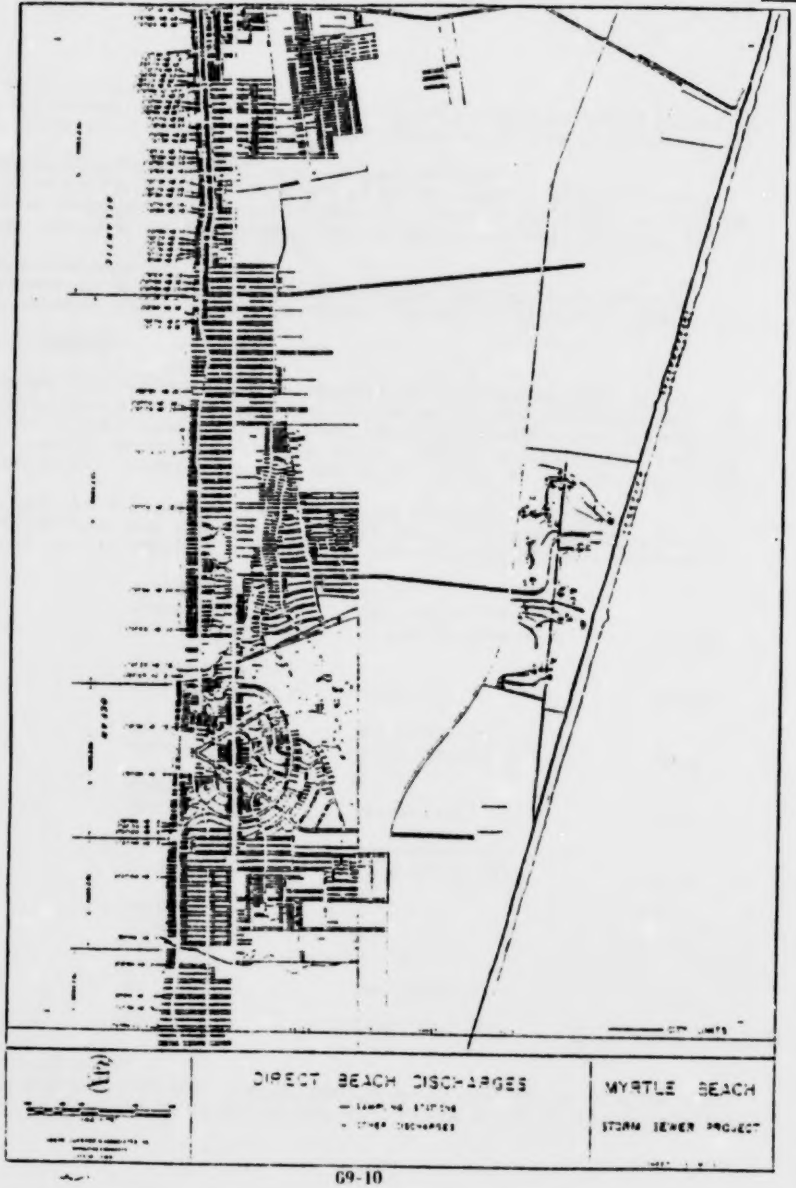
Cost evaluations of alternatives were made using a discount rate of 6 7/8%, an evaluation period of 20 years, service life of the pumping facilities of 30 years, and service life of structures and piping of 50 years.

The alternatives were evaluated in terms of initial costs, capital and O&M costs.

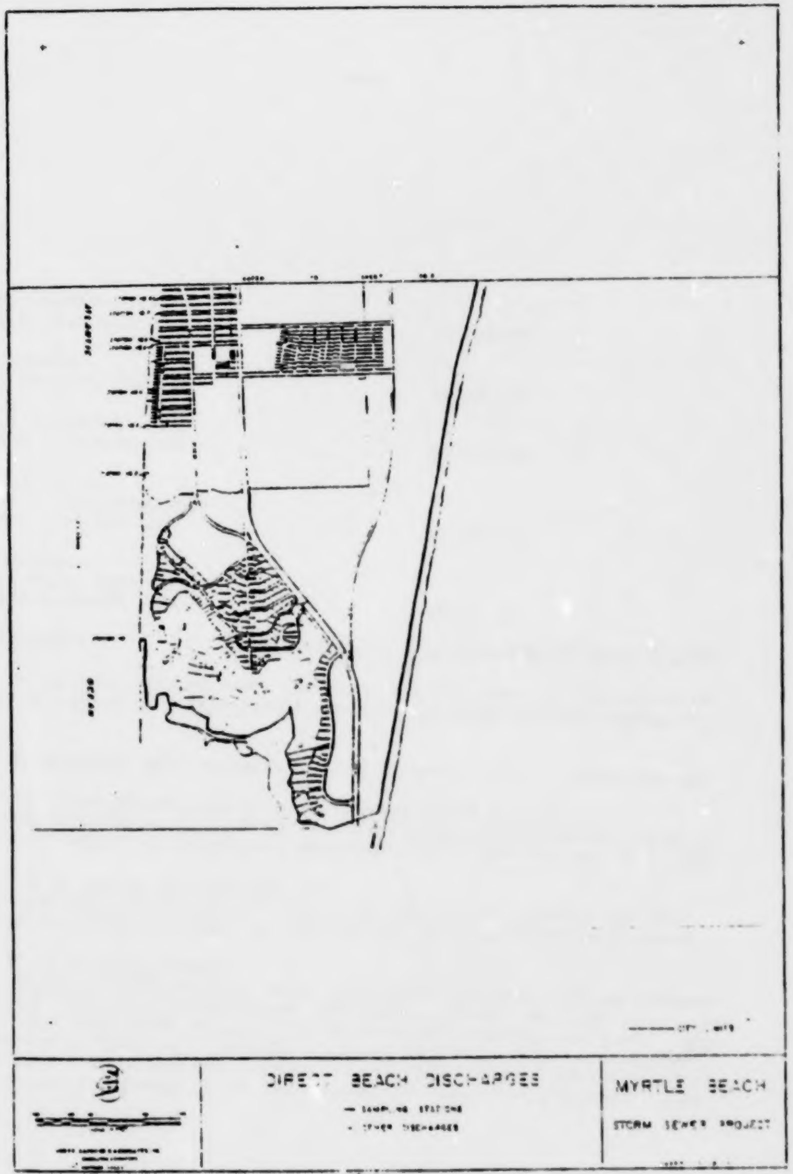
Several reports were submitted by Waccamaw RPDC which included evaluations of the selected alternatives. The final list with costs was the following:

Alternative	Construction Cost with Interception Sewer in Beach
Ocean Discharge from one outfall pipe with disinfection	32,800,000
Ocean discharge from four outfall pipes with disinfection	37,700,000
Ocean discharge from four diffusers	40,000,000
Intracoastal Waterway discharge	41,300,000
Ocean discharge from one diffuser	44,500,000

Reproduced from
best available copy.



69-10

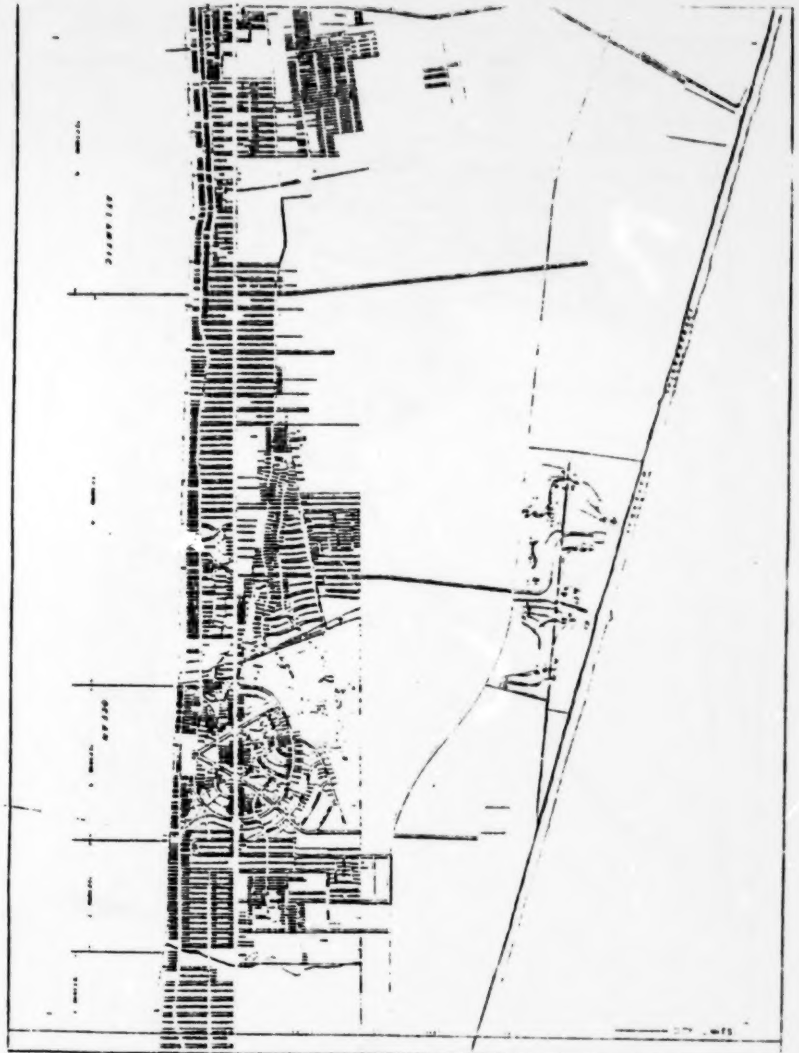


69-11

RANDOM SAMPLING STATIONS

MYRTLE BEACH
STORM SEWER PROJECT

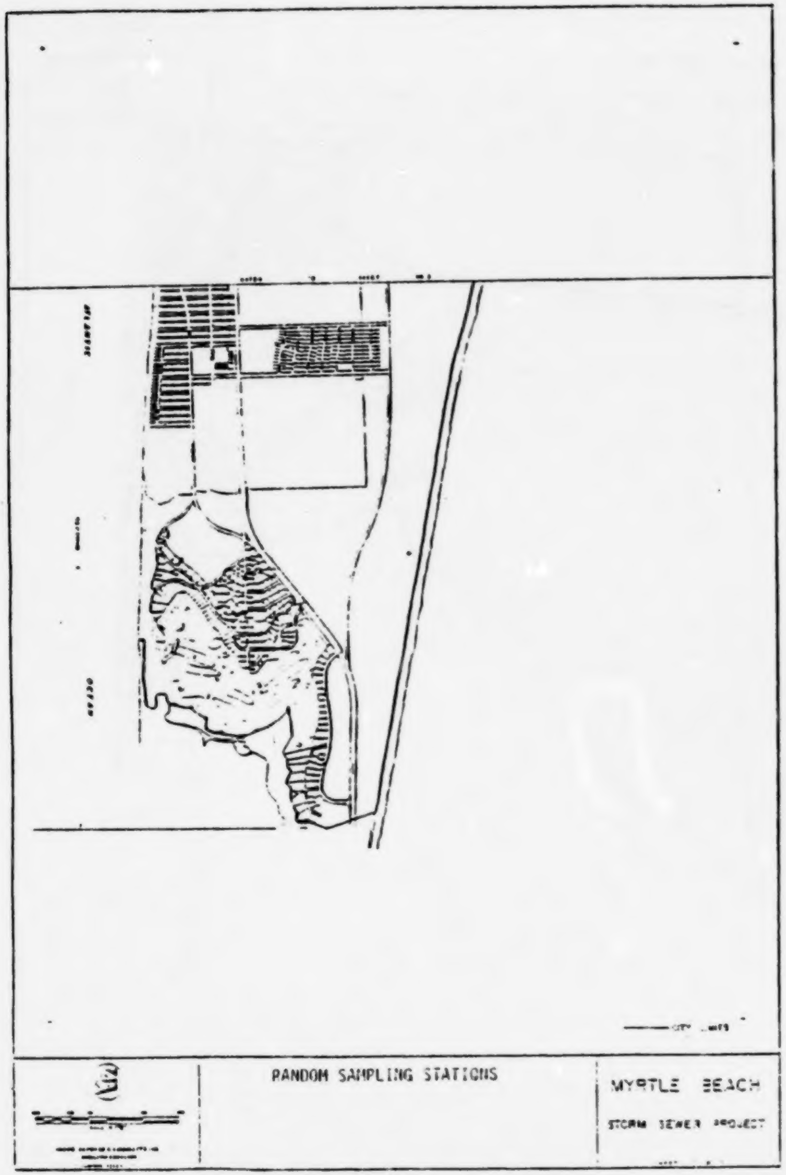
69-12



RANDOM SAMPLING STATIONS

MYRTLE BEACH
STORM SEWER PROJECT

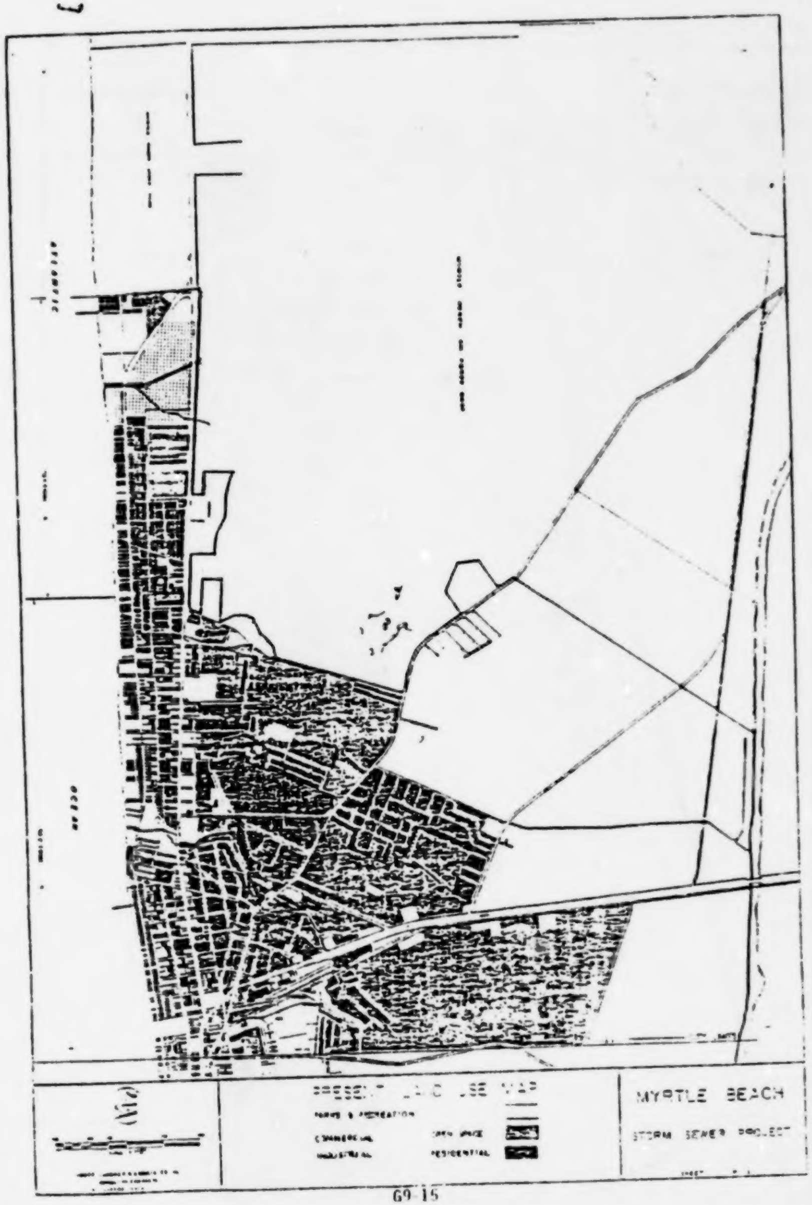
69-13



RANDOM SAMPLING STATIONS

MYRTLE BEACH
STORM SEWER PROJECT

G9-14



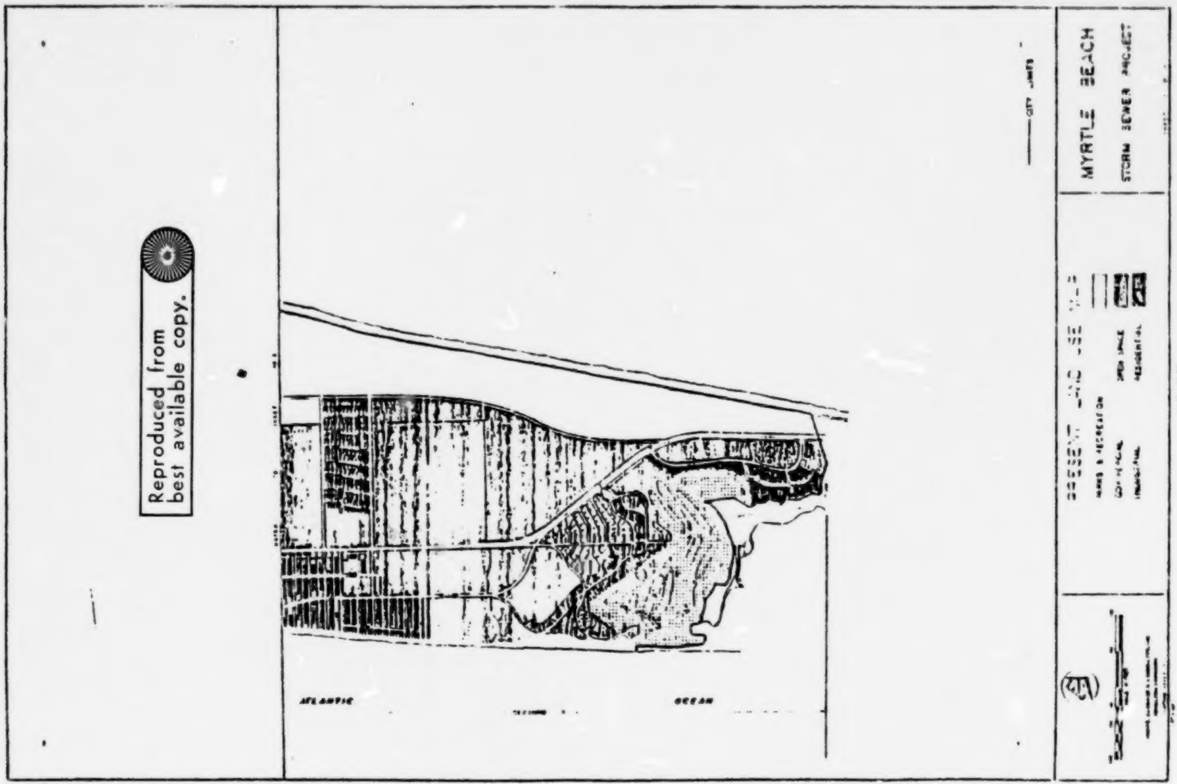
PRESENT LAND USE MAP

PARKS & RECREATION
COMMERCIAL
INDUSTRIAL
OPEN SPACE
RESIDENTIAL

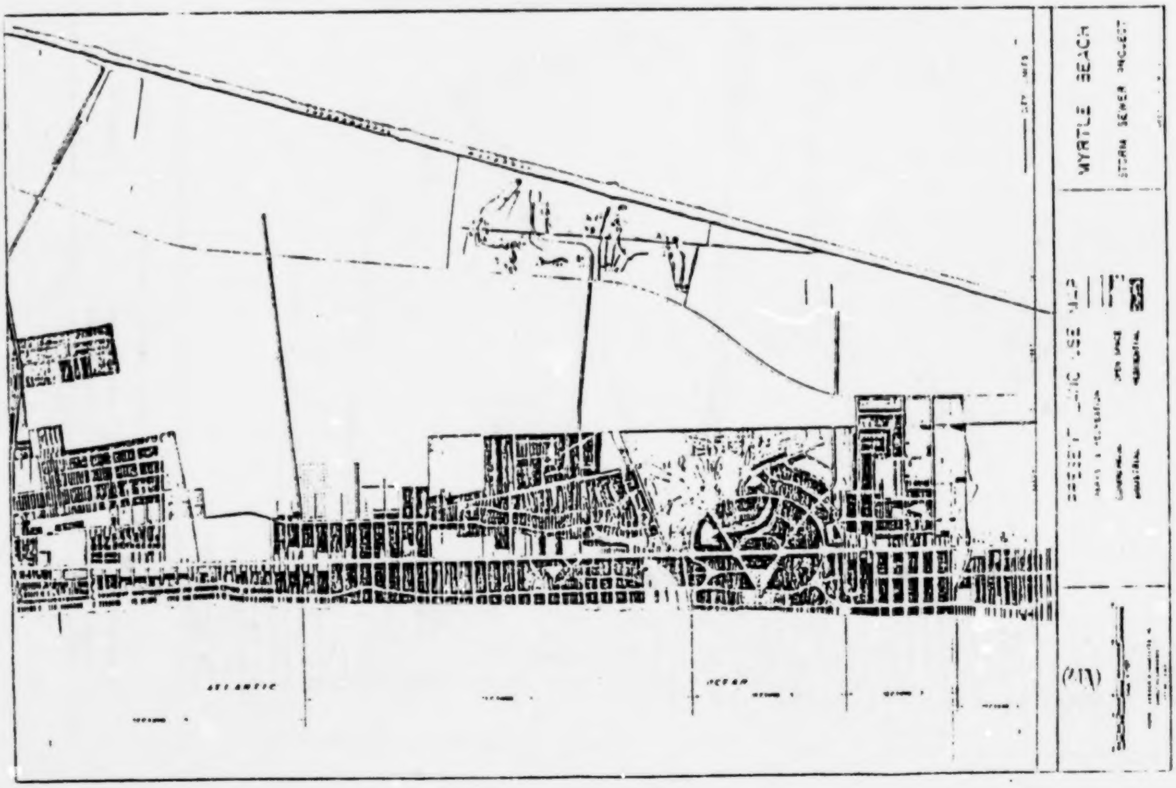
MYRTLE BEACH
STORM SEWER PROJECT

G9-15

Reproduced from best available copy.

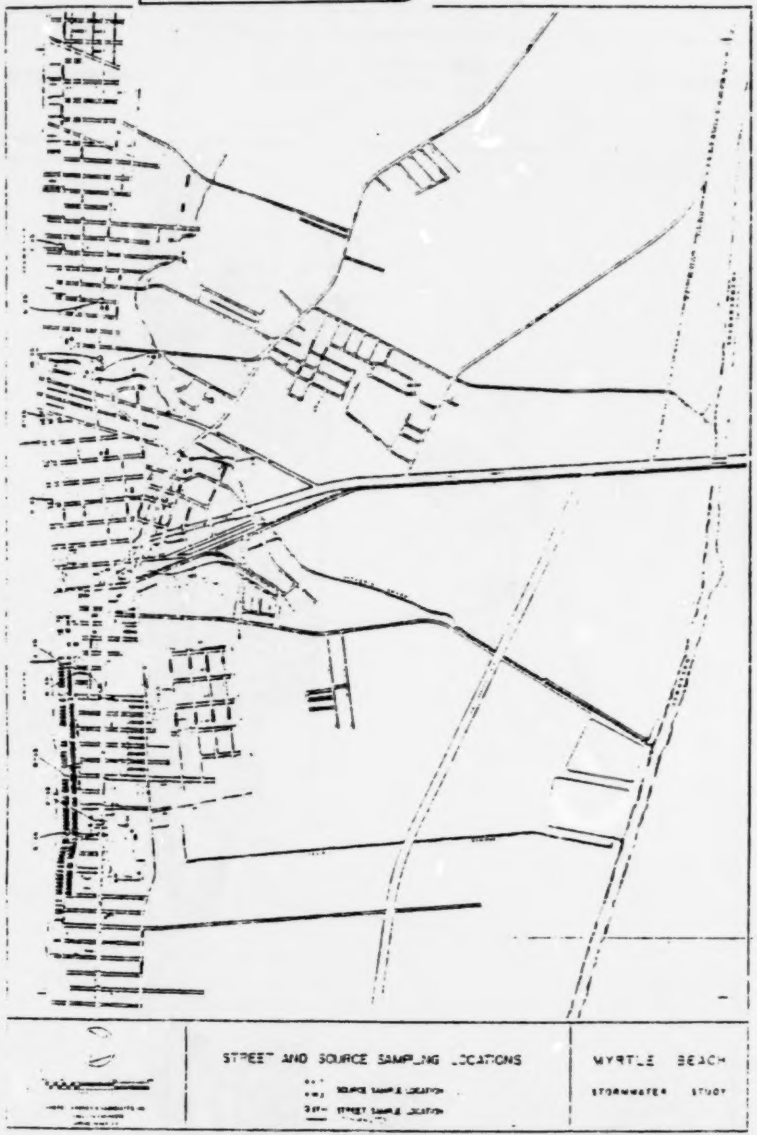


69-17



69-16

Reproduced from
best available copy.



G9-18

NATIONWIDE URBAN RUNOFF PROGRAM

NORTH CAROLINA DEPARTMENT OF
NATURAL RESOURCES

WINSTON-SALEM, NC

REGION IV, EPA

INTRODUCTION

In North Carolina, the industries and overall population are relatively dispersed. Consequently, water pollution effects characteristic of large urban cities in other parts of the nation are not pronounced. Only 37.3 percent of North Carolina's 1970 population of 5,082,059 lived in standard metropolitan statistical areas (SMSA's). Nationally, 68.5 percent of the population is centered in SMSA populations.

Seven SMSA's are designated in North Carolina: Asheville, Burlington, Charlotte-Gastonia, Fayetteville, Greensboro-Winston-Salem-High Point, Raleigh-Durham, and Wilmington.

The Piedmont, where 54.1 percent of the population is in urban areas, is the most urbanized region in the State.

A large portion of the state's urban population is located in a string of cities from Gastonia and Charlotte, through Greensboro to Raleigh. Similarly, a large portion of the manufacturing industry is concentrated in this area termed the "Piedmont Crescent." The Cresent is a dispersed urban region; no single city dominates. The development of this clustered cresent was originally influenced by a railroad line and has since been reinforced by the construction of Interstate 85. Three district clusters make up the Crescent: the Metrolina area (centered in Charlotte), the Triad (Greensboro-Winston-Salem-High Point), and the Research Triangle (Raleigh-Durham-Chapel Hill).

In North Carolina, several studies have been carried out to determine the magnitude of water quality problems associated with urban runoff. Many of these studies were conducted in the urbanized Piedmont Crescent. The results of the studies showed that the Central Business District and other commercial land use areas were found to generate the highest pollutant loadings for most of the pollutant parameters monitored. Additionally, work conducted by the Division of Environmental Management found urban streams in Asheville to be severely biologically degraded.

The Winston-Salem area was designated by DEM as a priority area in the first phase of statewide 208 planning process, due to the concentration of urban and industrial activities. Additional significance in choosing Winston-Salem as a study area lies in the fact that the city is the first major urban center (fourth largest city in NC) below the headwaters of the Yadkin River. Runoff from from almost all of this urban area is received ultimately by the Yadkin River, the major potable surface water supply for many communities downstream.

In conjunction with the Forsyth County Environmental Affairs Department, sampling in Winston-Salem was initiated in January, 1978, to examine the water quality impacts of both Central Business District (CBD) and residential land uses. Each stream station was sampled during low flow and several during stormflow conditions for nutrients, heavy metals, dissolved oxygen, BOD, and fecal coliforms. Biological sampling was also conducted on a quarterly basis in Tar Branch, the stream the Central Business District discharges into.

The results of this study were consistent with earlier studies. That is, concentrations of most pollutants were higher in the Central Business District during the period sampled.

In addition to monitoring for physical/chemical parameters, biological sampling was conducted which showed the urban streams to have "poor water quality conditions."

The urban stormwater section of the North Carolina Water Quality Management Plan identified various techniques that could be used to reduce urban runoff pollution. The purpose of the Winston-Salem urban runoff project was to evaluate some of the techniques mentioned in this plan under a variety of real world conditions.

PHYSICAL DESCRIPTION

A. Area

The Winston-Salem NURP project encompasses several jurisdictions including Forsyth County and the city of Winston-Salem.

Located in north central North Carolina in the middle Piedmont Plateau, Forsyth County is characterized by a foothill terrain. Elevations range from a low of about 700 feet along the Yadkin River to points of about 1100 feet along the divide between the Dan-Roanoke Basin and the Yadkin River Basin, with an average elevation of about 870 feet.

The soils of the county are extremely varied and highly intermingled. The soils present a wide range of percolation characteristics, depth to water table, depth to bedrock, erodability, and other factors.

The quality of the groundwater for Forsyth County is good and the mineral content is low. The dissolved solids content ranges from about 30 to 160 mg/l, but is generally between 50 and 100 mg/l.

Winston-Salem is the major urban area in Forsyth County and is located in the central part of the county. The city has a total land area of 61.6 square miles.

Approximately 81% of the land area in Winston-Salem is in residential and related uses. Industry accounts for about 7% of the area. Commercial use accounts for another 7%, and the remaining 5% is in vacant lots.

The average annual temperature is 50.5°F, with an average monthly temperature of 41°F in December to 78°F in July. Precipitation averages about 44.2 inches per year.

Summer rainfall is characterized by thunderstorms with occasional hail. Winter rainfall results mainly from low-pressure storms and is less variable than summer rainfall. The total snowfall in Forsyth County every winter ranges from one inch to two feet with an average total amount of nine inches.

B. Population

The 1978 population estimate for Forsyth County is 233,600. Future projections done in 1976 were 238,200 by 1980 and 260,900 by 1990.

C. Drainage

Drainage patterns in Forsyth County follow three main directions. A very small fraction flows eastward and is received by the Cape Fear River. Approximately 22% of the county's drainage flows north and is contained within the Dan-Roanoke River basin. Southwestward flow into the Yadkin River accounts for approximately 78% of the drainage.

Reproduced from
best available copy.

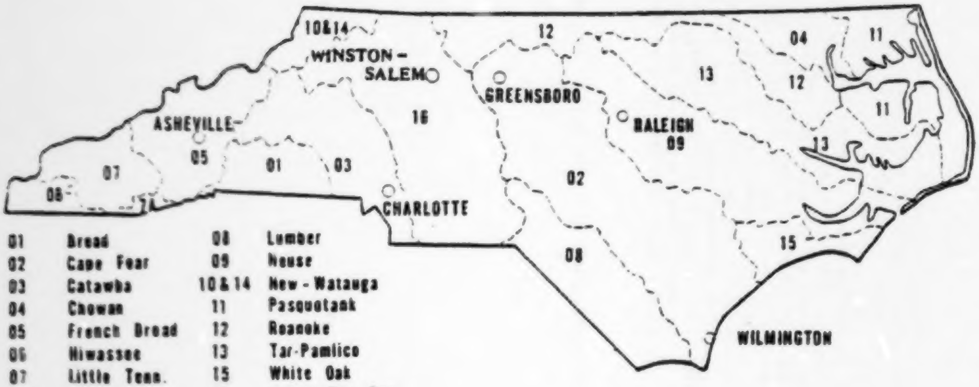
The Yadkin River is located on the western boundary of the county. The two major tributaries flowing into the Yadkin River from Forsyth County are Abbott's Creek (drainage 25.3 square miles in Forsyth County), and Muddy Creek (drainage 159.2 square miles in Forsyth County). The Muddy Creek basin drains a major portion of urban Forsyth County, including all of Winston-Salem, portions of the municipalities of Kernersville and Rural Hall, and portions of the unincorporated communities of Walkertown and Clemmons. Muddy Creek tributaries and their drainage areas from north to south include Mill Creek (32.2 square miles), Silas Creek and Little Creek (18.9 square miles,) Salem Lake and Salem Creek (69.6 square miles), and the Forsyth County portion of South Fork Creek (36.8 square miles). The Abbott's Creek watershed drains southward into High Rock Lake. The remaining of the county is westard directly into the Yadkin River, eastward into the Haw and Deep Rivers, and northeastward into the Dan-Roanoke River Basin. These drainage areas are shown in Figure III.A.

D. Sewerage System

The entire area of Winston-Salem is served by separate storm sewers.

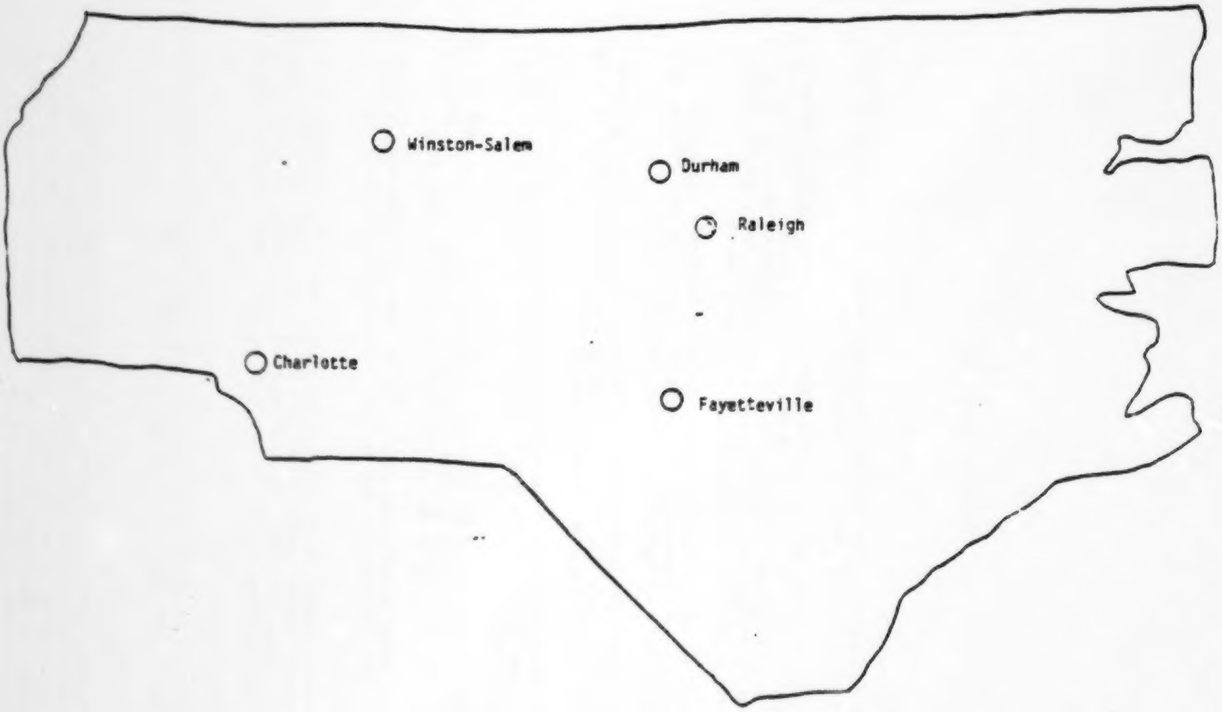
NORTH CAROLINA

RIVER BASINS



01	Broad	08	Lumber
02	Cape Fear	09	Neuse
03	Catawba	10&14	New-Watauga
04	Chowan	11	Pasquotank
05	French Broad	12	Roanoke
06	Hiwassee	13	Tar-Pamlico
07	Little Tenn.	15	White Oak
07A	Savannah	16	Yadkin-Pee Dee

G10-7



G10-6

THE STATE OF NORTH CAROLINA

PROJECT AREA

I. Catchment Name - NC 1023 Ardmore

A. Area - 324 acres.

B. Population - 1846 persons.

C. Drainage - Burke Branch is a tributary draining the Ardmore residential district.

D. Sewerage - Drainage area of catchment is 97.7% separate storm sewers. 2.3% is served by on-site systems. All of the separate storm sewered area has curbs and gutters. Streets consist of 26 miles of asphalt.

E. Land Use

38.9 acres (12%) Urban Parkland.

5.73 acres (2%) is Light Industrial.

6.28 acres (2%) is Linear Strip Development.

.95 acres (< 1%) is 78 dwelling units per acre residential.

269.36 (83%) is 2.5 to 8 dwelling units per acre.

II. Catchment Name - NC 1013 Central Business District

A. Area - 22.7 acres.

B. Population - 0 persons.

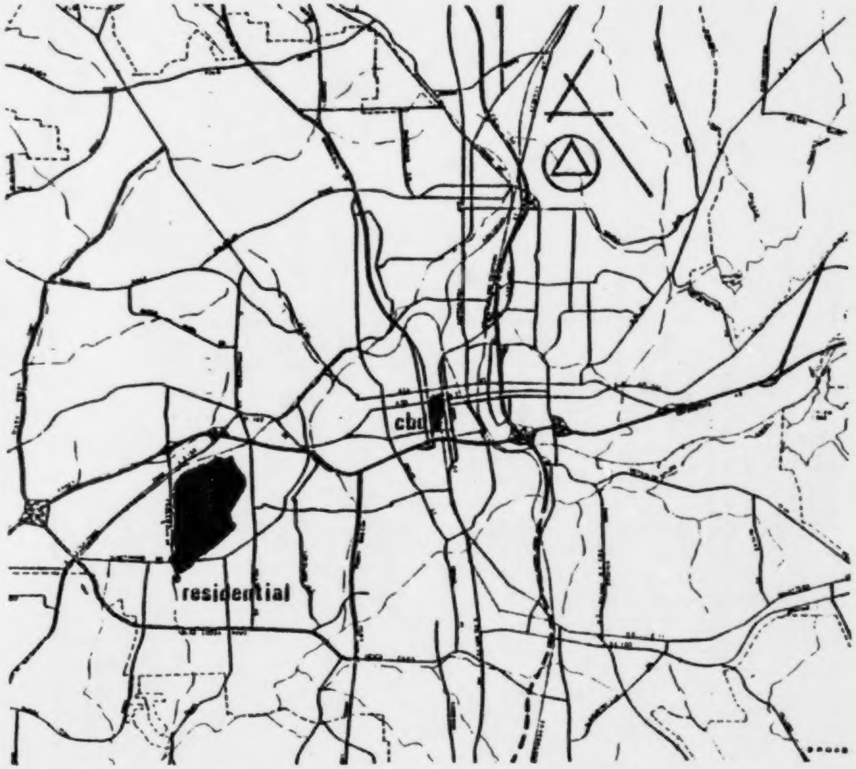
C. Drainage - Site is a storm sewer draining into Tar Branch Tributary to Muddy Creek.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers. All of the separate storm sewered area has curbs and gutters. Streets consist of 3.68 miles of asphalt.

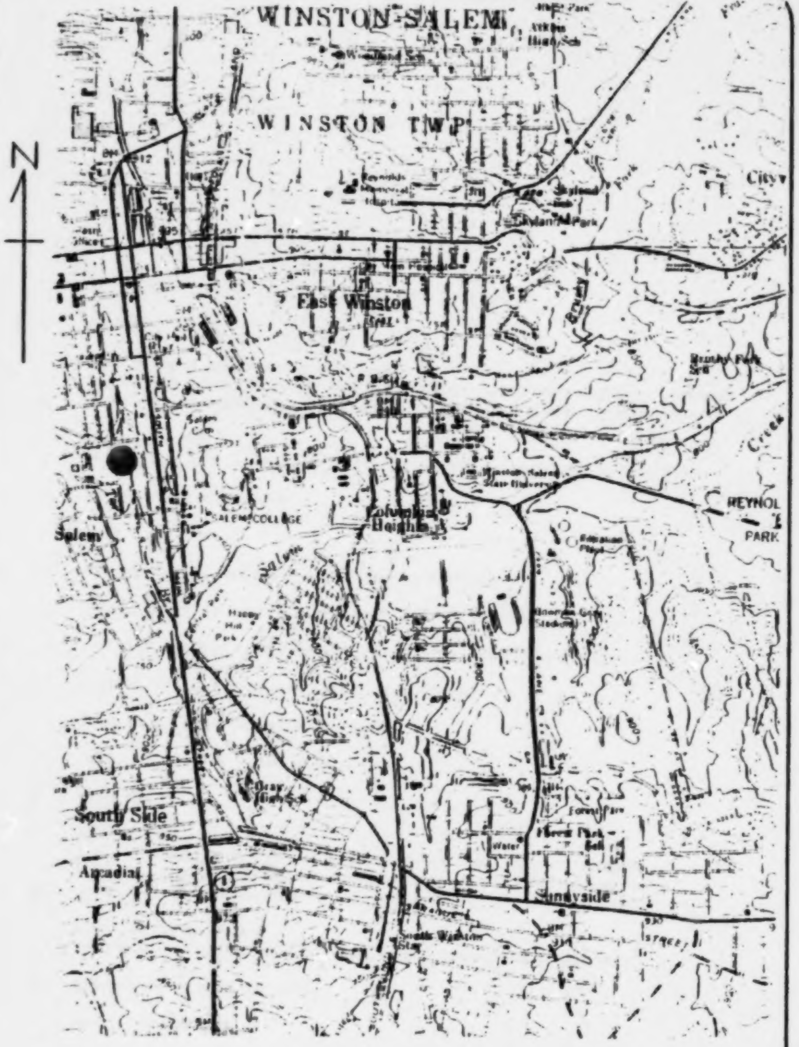
E. Land Use

22.7 acres (100%) is Central Business District

LOCATION OF WATERSHEDS TO BE MONITORED

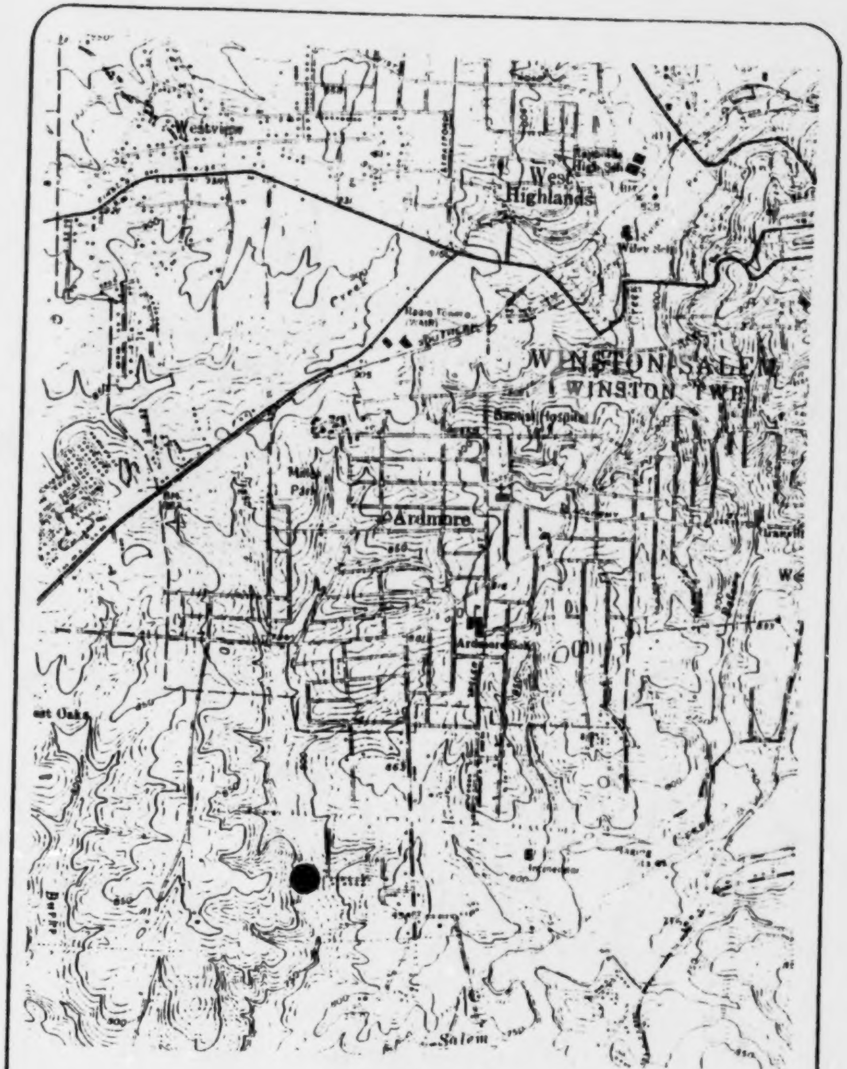


Reproduced from best available copy.



Winston-Salem, N.C.
Central Business District Site

G10-10



Winston-Salem, N.C.
Ardmore Residential Site

G10-11

PROJECT DESCRIPTION

A. Major Objective

The primary objective of the Winston-Salem NURP project is to evaluate street-related, non-structural practices for relative pollutant removal cost and effectiveness potentials under a variety of real world conditions. Street cleaning and catch-basin cleaning activities in already developed urban areas were evaluated. Tymco Regenerative Air Sweepers and various cleaning frequencies were investigated in small-scale field tests and large-scale program tests in selected watershed. Small-scale tests included determination of accumulation rates of street surface solids by weight and particle size distributions and associated, attached contaminants.

Larger scale programmatic tests included cost determinations, as well as benefits to water quality, leading to the development of an optimal cost-effective program.

Determination of the seasonal atmospheric fallout contribution which can accumulate on streets and other impervious surfaces and subsequently be washed off and a determination of the pollutant contributions washed out of the atmosphere by precipitation were made.

The watersheds monitored are representative of about 88% of the land area of Winston-Salem, and a large percentage of most urban areas in North Carolina. The CBD watershed was studied because of the associated high concentration of pollutants and potential efficiency of management for this type of land use. The residential area, although having relatively lower pollutant concentration in runoff accounts for a large majority of the city area and thus a large overall pollution potential.

B. Methodologies

The full scale tests of Best Management Practices was divided into four subtasks. These four subtasks included 1) accumulation rate determinations 2) pollutant/particle size determinations, 3) street cleaning equipment performance determinations, and 4) catch basin cleaning performance determinations. Each of these tasks were necessary to accomplish the main objective of the study.

1. Accumulation Rate Determinations

A knowledge of the accumulation rates of solids on street surfaces and surrounding impervious surfaces is important in determining the amounts of associated pollutants that accumulate on these surfaces. Past studies had shown that accumulation rates vary widely between areas due to street surface characteristics, land use patterns, traffic conditions and other local factors.

Solids accumulations within each watershed were studied by collecting representative samples from the streets and sidewalks. An experimental design was carried out in each watershed to determine the number of subsamples needed to statistically represent the variation found in the watershed. Due to cost constraints however, only 50 strips were chosen randomly throughout the watershed. This number is less than the number needed to adequately represent the variation.

The experimental design study was carried out in each season, in both watersheds, to determine the required number of subsamples for a representative watershed sample.

Accumulated solids on strips of street were then collected with a small-scale, hand-held, vacuum cleaner capable of removing and retaining particles as small as five microns.

Watershed accumulation studies were carried out in essentially the same manner as the experimental design studies. The exception was that larger capacity vacuum cleaners were used in the full scale tests to accomodate the collection and retention of the larger watershed representative "sample". Solids accumulation within each watershed was determined by taking weekly samples within each watershed for a period of 12 months.

Collected solids in each sample were analyzed for wet and dry weight, particle size distribution and median paticle size class based on the weight fractions of size classes. All particle size fractions were retained for each watershed. Size fractions from each weekly sample were composited on a monthly basis by watershed and analyzed for several pollutants.

Because of the possibility of across the street variation in solids loading on streets and sidewalks, seasonal studies were carried out to evaluate this possiblity. Street lengths of 10 feet considered to be representative of the test areas were chosen. A number of pavement strips of different width were vacuumed, solids collected, removed, and retained for particle sizing and pollutant analysis.

2. Pollutant/Particle Size Determinations

Many of the accumulation rate determination studies have associated particle sizing of solids collected, and pollutant analyses for each separated particle size class. These pollutant analyses are important in determining the relationship between particle size and associated pollutants and in drawing conclusions from these analyses.

The weekly samples collected in the watershed accumulation studies were separated into particle size fractions which were weighed and retained. These size fractions from weekly samples were composited by size class on a monthly basis. The composited, monthly size fractions were analyzed for eight pollutants of interest.

3. Street Cleaning Equipment Performance Determinations

Vacuum cleaners were investigated under a variety of real-world operating conditions to determine the pounds of solids removed per curb-mile and the particle size distributions in samples taken from street surface tests strips before and after cleaning operations.

Particle size determinations provided for estimates of associated pollutants removed based on information determined in the pollutant/particle size association studies. Calculations were also made to determine the median particle size in each of the samples to allow for determinations of equipment performances to be made as a function of particle size.

4. Catch-Basin Cleaning Performance

The purpose of this subtask was to determine the accumulation rates of solids in test catch basin structures. Three test structures were chosen to represent different siting positions. The pollution abatement potential of cleaning these structures at various intervals was investigated. Accumulation periods of two weeks, one month, and two months were studied.

Practice effectiveness was evaluated for different accumulation periods by determining dry weight amounts (pounds) of solids removed per structure cleaned. Representative solid samples were removed from the catch/basins being studied after cleaning.

Precipitation events and other activities influencing accumulation were closely documented.

Water quality samples were taken at the two selected watersheds before and after implementation of the BMP's. Total loads washed off and concentrations were compared to before and after BMP implementation as well as to water quality standards promulgated by the state of North Carolina.

Two sites were also constructed in the Central Business District to supply source input for background deposition, and street and curb deposition from atmospheric sources.

C. Monitoring

Automatic samples were taken at both monitoring locations. ISCO model 1870 flow meters and ISCO model 1680 high speed sequential samplers were used. Discrete samples were taken at both sites.

Aerochemetrics Model 301 wetfall/dryfall samplers were used to collect the atmospheric deposition samples. Wetfall samples were collected on an event basis. Dryfall samplers were collected on a monthly basis.

D. Controls

As described in the Methodologies section, both street sweeping practices and catch-basin cleaning practices were evaluated. The methods used for these evaluations are described in Section B.

PROBLEM

A. Local Definition

Several studies have been conducted in North Carolina to determine the extent of degradation of urban streams. These studies in Durham, Raleigh, Asheville, and Winston-Salem have shown that, under present conditions, almost all urban streams will be unable to meet the 1983 water quality goals.

Many of these studies were conducted in the urbanized Piedmont Crescent. The results of the studies showed that the Central Business District and other commercial land use areas were found to generate the highest pollutant loadings for most of the pollutant parameters monitored. Significantly high concentrations of nutrients and heavy metals, notably phosphorus and lead, respectively were observed. Additionally, work conducted by the North Carolina Division of Environmental Management (DEM) in conjunction with the Land of Sky Regional Council of Governments found urban streams in Asheville to be severely biologically degraded.

The Winston-Salem area was designated by DEM as a priority area in the first phase of the statewide 208 planning process, due to the concentration of urban and industrial activities. Additional significance in choosing Winston-Salem as a study area lies in the fact that the city is the first major urban center below the headwaters of the Yadkin River. Runoff from almost all of this urban area is received ultimately by the Yadkin River, the major potable surface water supply for many communities downstream.

In conjunction with the Forsyth County Environmental Affairs Department, sampling was initiated in January 1978 to examine the water quality impacts of both Central Business District (CBD) and residential land uses. Each stream station was sampled during low flow and several during stormflow conditions for nutrients, heavy metals, dissolved oxygen, BOD and fecal coliforms. Biological sampling was also conducted on a quarterly basis in Tar Branch, the stream the Central Business District discharges into. The data from these studies showed distinct differences in pollutant concentrations from the residential areas and the CBD for several parameters. Concentrations of most pollutants were higher in the CBD during the period sampled.

The monitoring also showed that some water quality problems also exist during dry weather (low flow) conditions. During high flow conditions, concentrations exceeding proposed North Carolina standards were demonstrated for lead, mercury, iron, and fecal coliform bacteria. Elevated levels associated with high flows, but not exceeding proposed standards were shown for zinc, several nutrient parameters, BOD_5 and COD. However, high concentrations of several of the heavy metals, particularly mercury, were found during low flow conditions. High fecal coliform concentrations were also found during low flow conditions.

In addition to the monitoring for physical/chemical parameters, biological sampling was conducted which showed the urban streams to have "poor water quality conditions".

The urban stormwater section of the North Carolina Water Quality Management Plan identified various techniques that possibly could be used to reduce urban runoff pollution. These techniques include both structural and non-structural practices. The objective of the Winston-Salem study is to evaluate some of the non-structrual techniques for relative pollutant removal effectiveness potentials under a variety of real world conditions.

B. Local Perception

The "North Carolina Stormwater Manager" is a publication put out bi-monthly by the Water Resources Research Intstitute at North Carolina State University. The purpose of the newsletter is to help consultants, city engineers and public works directors in North Carolina who are concerned with stormwater management communicate with each other. The state has always been a leader in the field of stormwater management.

Because of the local interest in environmental problems, Forsyth County formed an Environmental Affairs Board in 1976. The purpose of the board is to encourage the wise and beneficial use of the natural environment and minimize the adverse effects of environmental contaminants on human health. The Forsyth County Environmental Affairs Board has played a very active part in the Winston-Salem NURP project.

NATIONWIDE URBAN RUNOFF PROGRAM

TAMPA DEPARTMENT OF PUBLIC WORKS

TAMPA, FLORIDA

REGION IV, EPA

INTRODUCTION

The City of Tampa Department of Public Works is charged with solving the, at times, conflicting problems of urban flood control and runoff generated water quality deterioration. Large portions of Tampa have been developed with little, if any, drainage provisions and the consequent flooding is of primary concern to the citizens. At the same time, urban runoff has been identified as a significant source of pollution to several important local water bodies (the Hillsborough River including a reservoir, and portions of Hillsborough Bay). The areawide Water Quality Management Plan recently completed by the Tampa Bay RPC classified all land areas within the City limits as segments with serious water quality problems. The Florida Department of Environmental Regulation (DER) has designated all stream segments within the Tampa Bay Region as water quality limited, i.e., point source treatment is expected to be insufficient to achieve acceptable water quality and thus nonpoint sources must be considered a significant portion of the problem. The DER also recently enacted stormwater runoff permitting rules which call for a reduction of pollution to comply with water quality standards.

To help find a solution to all of these problems, the Tampa Department of Public Works is participating in the Nationwide Urban Runoff Program. Tampa DPW hopes to use the data collected in the NURP program and develop a plan for the management of stormwater runoff in the Tampa area.

PHYSICAL DESCRIPTION

A. Area

The City of Tampa lies at the northeast corner of Tampa Bay and partially encompasses the Hillsborough Bay System (Figure 1). Hillsborough Bay covers approximately sixty-five square miles and surrounded by a large metropolitan complex which supports extensive industrial activity and serves as a major shipping port. The Bay is highly eutrophic, and anoxic conditions have been reported. The city of Tampa is bisected by the Hillsborough River. The Bay and the River serve as the primary ultimate recipients of stormwater discharge. The Hillsborough River originates some 55 miles northeast of Tampa in the Green Swamp.

Approximately ten miles from its mouth, the river has been dammed to create the Hillsborough River reservoir. The predominantly forested and agricultural (but increasingly urban) drainage basin above the dam is estimated at 630 square miles. Below the spillway, approximately sixty square miles of largely urban area drain into the river.

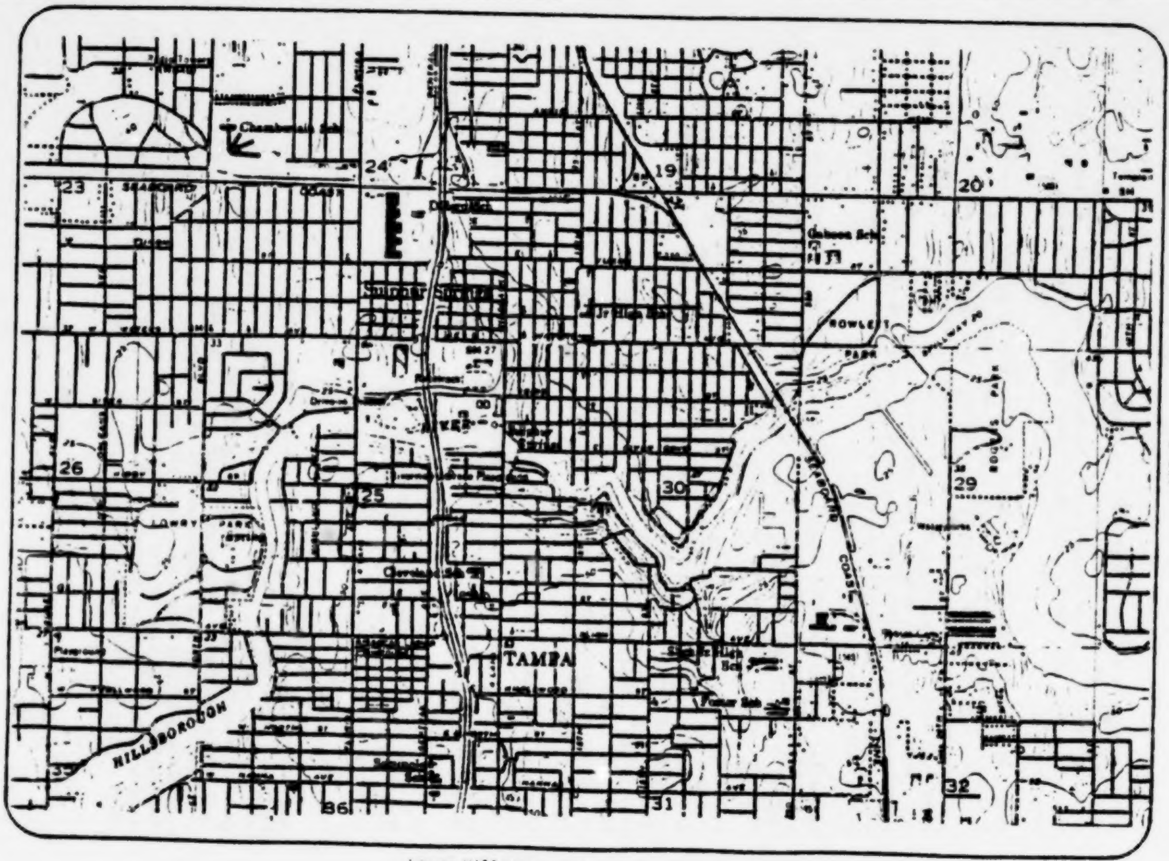
The Tampa Bay area is a humid sub-tropical area. Average annual rainfall is 48.9 inches, 60% of which falls between June and September (National Oceanic and Atmospheric Administration). The rainfall is associated with seasonal thunderstorms and frontal activity.

Easterly winds prevail during the summer and northerly winds during the winter. Mean monthly temperatures range from 16.2°C (61.2°F) in January to 27.8°C (82°F) in August.

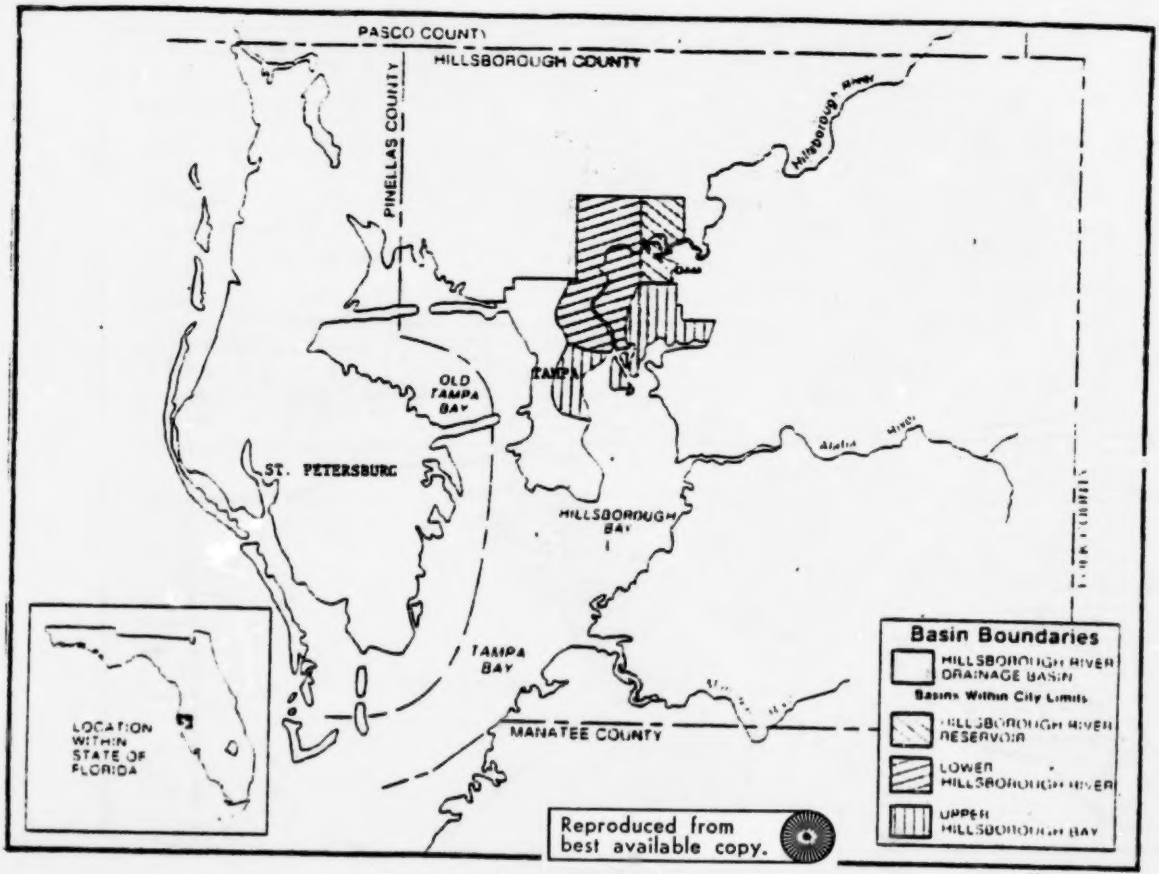
Tampa exhibits flat to gently undulating terrain, typically characteristic of the Gulf Coastal Lowlands in which it is included. Elevations range from sea level along Hillsborough and Tampa Bay, to 87 feet above mean sea level (MSL) in the extreme northeastern parts of the City. The remnants of three shorelines and four marine terraces, attributed to the rise and fall of the sea during the periods of continental glaciation, have been identified.

A close examination of a topographic map of the City reveals that the majority of the City is less than 25 feet above mean sea level (MSL). This low coastal area, which originates at the Bay margin, varies considerably in configuration and is extremely susceptible to adverse weather conditions, specifically, high tides and tropical storms. Historical evidence confirms the assumption that a significant portion of the City is subject to frequent and recurrent flooding due to adverse weather conditions, low and flat topography, and a lack of drainage facilities.

Flooding is a serious natural hazard that should be avoided. Because Florida is prone to periods of drought or long periods of less than average rainfall, many areas which are subject to flooding appear to be high and dry. Especially deceptive to many people is the extent of the floodplain associated with tropical storms. The low-lying areas surrounding the Bay are extremely attractive for residential neighborhoods, and consequently, are well developed. Since the last major hurricane (1960), extensive development in the coastal floodplain has occured. Realistically, the next hurricane can inflict massive and catastrophic damages upon the low-lying areas within the City.



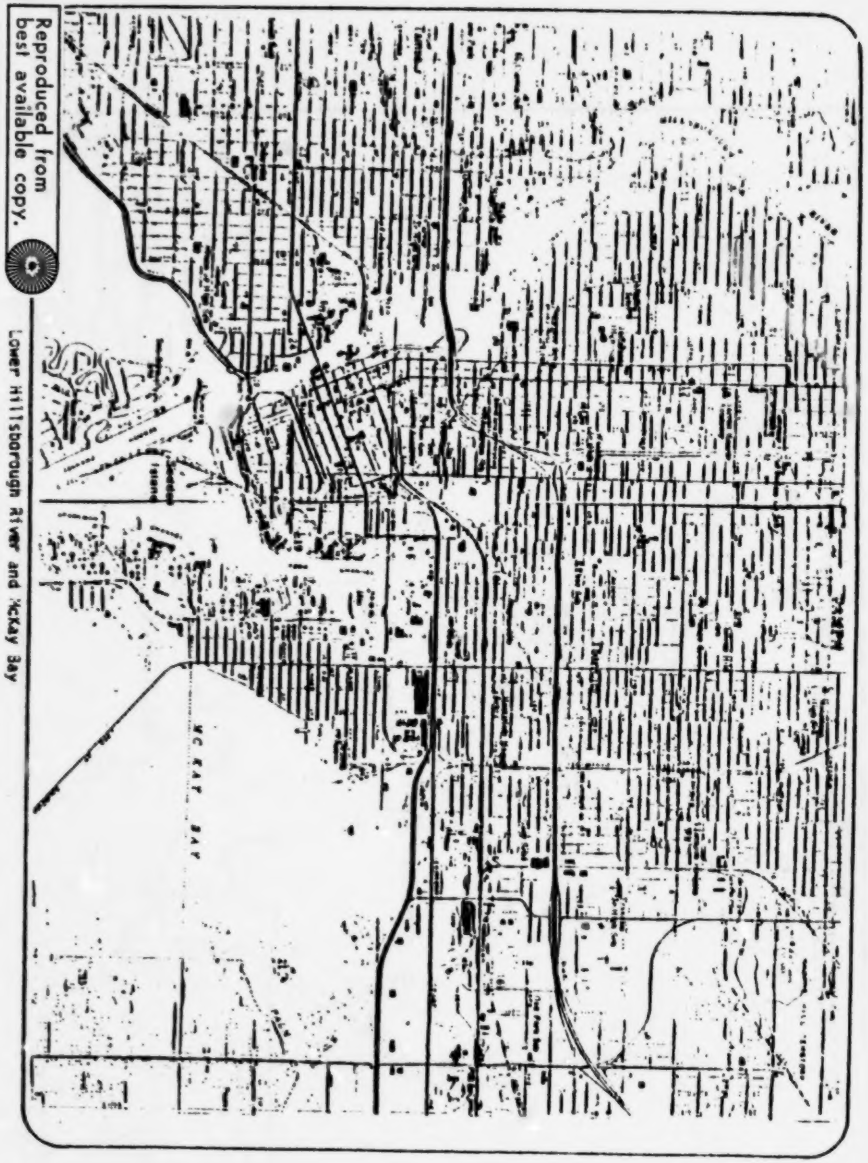
Lower Hillsborough River



Reproduced from best available copy.

Figure 1 City of Tampa Drainage Areas

Reproduced from
best available copy.



Lower Hillsborough River and McKay Bay

Beyond the low-lying areas subject to flooding, extensive areas within the City are representative of karst topography. Evidenced primarily in the northern extent of the City, karst topography is characterized by springs, disappearing streams, depressions, water-filled depressions, subterranean cavities, and sinkholes.

Tampa may be considered as being almost entirely developed, with few large tracts of open land remaining. This state of development is significant in that the development process has altered existing vegetation patterns, drainage, soils and groundwater characteristics. For example, development of roads, sidewalks, and roof tops increases the amount of water that "runs off" a site; this extra runoff, above the natural rate, necessitates the construction of a storm sewer system. This modification of drainage, from a natural to an artificial urban stystem, is essentially complete within the City although construction of storm sewer systems is not yet complete.

Within the incorporated city limits of Tampa, a relatively small amount of land remains vacant for development. The majority of vacant land exists near MacDill Air Force Base and south of Tampa Airport -- undeveloped land is also available around McKay Bay and on Seddon Island.

Industrial land uses in the City are heavily concentrated in the areas around the port facilities, with the greatest percentage located along the north side of Adamo Drive from the Palm River area on the east to 13th Street on the west. From this location, industrial usage extends southward to Hooker's Point. Another large concentration of industrial usage which exists apart from the port facilities is located just north of Busch Boulevard and east of 30th Street. This area is the Tampa Industrial Park which includes the well-known tourist attraction, Busch Gardens. Smaller concentrations of industry exist at the Port of Tampa and west of Westshore Blvd. in the vicinity of the Westinghouse Plant.

Commercial development in Tampa has in many cases developed in the traditional strip commercial fashion along the length of major traffic arterials. The primary commercial strips are found on Hillsborough Avenue, Kennedy Boulevard, East Broadway, Busch Boulevard, Dale Mabry Highway, Armenia Avenue, Florida Avenue, and Nebraska Avenue.

The majority of land in the City is in residential usage, primarily single family, with multi-family the second largest category, but representative of a significantly smaller amount of acreage. Mobile home parks are a much smaller residential use in the City.

B. Population

The City of Tampa is located in west central Florida. The corporate limits encompass 84.45 square miles (8.12%) of Hillsborough County; approximately half of the total population of Hillsborough County resides within Tampa. Gross population density per square mile is 3,351; total population (1978) is 282,741. This figure represents a 4 percent increase since the 1970 Census. The minor population increase is not characteristic of the Tampa Bay region; compared to most other jurisdictions, Tampa's population is increasing at a very slow rate. The level of population concentration generally increases as one moves from the downtown Central Business District (CBD) to the corporate limits. As a result, large portions of the population are located in the North Tampa and Interbay areas.

C. Drainage

The City of Tampa is divided into three major drainage areas: the Hillsborough River, Hillsborough Bay, and Old Tampa Bay. Old Tampa Bay is not addressed at all in this study. (see map)

Hillsborough River

The Hillsborough River originates approximately 50 miles northeast of the City of Tampa in the Green Swamp. The Green Swamp is a large, ill-defined, wetland area situated in Sumter, Polk, Pasco, and Lake counties. The swamp has been determined to be situated directly over a recharge subsurface aquifer. The swamp is also the origin of two other major central Florida rivers, the Withlacoochee and Oklawaha. The watershed for the Hillsborough River is generally considered to be approximately 630 square miles; however, exact delineation of the basin's area is difficult due to the lace of readily defined interfluves in the Green Swamp headwaters. Under certain high water conditions, the Hillsborough River receives drainage that would normally be considered as being part of the Withlacoochee basin. The Army Corps of Engineers estimates that intermittent overflows as high as 35,000 cfs have occurred in the past (1934) but that the annual average overflow is about 30 cfs.

Proceeding downstream from the Withlacoochee "overflow channel", the river shows a relatively steep gradient; however, the floodplain remains quite expansive, with widths varying between 2,000 to 6,000 feet. Fox Branch enters the Hillsborough at this point. Fox Branch extends roughly 8 miles to the southeast, to its origin near the settlement of Socrum. Most of Fox Branch extends through unimproved pasture, but some citrus and improved pastures are apparent. Flows range from 0 to 100 cfs. Downstream, Crystal Springs discharges to the Hillsborough through a half mile run. The springs flow year-around and assure a base flow in the river. Discharges vary from 20 to 150 cfs. Big Ditch is a 3-mile long tributary flowing due west into the river. The headwaters of Big Ditch originate in an area of surface mining and phosphate production.

Downsteam, an unnamed tributary flows south 5 miles through areas of improved pasture, citrus, and at least 20 confined feeding operations around the outskirts of the City of Zephyrhills.

Blackwater Creek is the first major tributary to the Hillsborough downstream from Big Ditch. This watershed is characterized by extensive channelization that has been developed to manage improved pasture and citrus groves within the watershed. Furthermore, the headwaters of Blackwater Creek and its major tributary, Itchepackesassa Creek, drain urban and suburban development in and around Plant City. Discharges from Blackwater range from 0 to 5,500 cfs. As many as 15 confined feeding operations have been identified within the Blackwater watershed.

Proceeding downstream, an intermittent stream known as Two-hole Branch discharges into the Hillsborough. Two-hole Branch drains primarily unimproved pasture. At this point, the Hillsborough River is associated with a vast hardwood swamp. Two tributaries, the New River and an unnamed tributary, also enter at this point. The New River drains an extensive area of improved pastures and rangeland, and has been channelized over much of its length. The unnamed tributary to the west of New River has similar characteristics.

The Hillsborough River, at this point, is ill-defined as it flows through the massive hardwood swamp. This swamp is the location of the lower Hillsborough River Detention Area, and encompasses approximately 15 square miles. The detention area, coupled with the nearly complete Tampa Bypass Canal, is intended to alleviate downstream flooding along the uranized portions of the Hillsborough River.

Several other tributaries also drain into this hardwood swamp, including Holloman's Branch, Flint Creek, Cow House Creek, Clay Gully and Trout Creek. Holloman's Branch is an intermittent stream that is largely channelized. It drains rangeland, improved pasture, and several confined feeding operations. Flint Creek originates at Lake Thonotosassa, which in turn is fed by Baker Creek and Pemberton Creek. Baker Creek and Pemberton Creek drain areas of mixed land-uses, including hardwood swamp, improved pasture, rangeland, suburban areas, and a small industrial area. Lake Thonotosassa is the largest lake in Hillsborough County at 830 acres. Its stage is regulated by a weir at the outfall to Flint Creek. Varying over a range of 2 feet, maximum lake depth is 14 feet with the deeper areas being covered with benthic muck, a result of phytoplankton fallout and organic wastes (citrus pulp) from industrial sources tributary to Baker Creek. Lake Thonotosassa experienced the largest fish kill in the U.S. in 1969. Flint Creek discharges into the Hillsborough via an unchannelized section of hardwood swamp. Average discharge is 20 cfs, with a range from 0 to 350 cfs.

Cow House Creek is a natural meandering channel of the Hillsborough and is undergoing substantial modification due to the construction of the Tampa Bypass Canal. Trout Creek and Clay Gully drain predominately land uses north of the Hillsborough. Both creeks drain into the river through a series of swamplands which probably reduces water quality problems.

Cypress Creek is the last major tributary in the rural segment of the Hillsborough River. Indeed, several portions of the lower reaches of Cypress Creek contain suburban residential land-uses, including a small airport and several minor commercial establishments. The upper reaches of Cypress Creek basin lies within a trough (50-70 feet) in the potentiometric surface of the Floridan Aquifer. Thus, the potentiometric level results in the discharge of considerable ground water into Cypress Creek.

The Hillsborough River segment downstream from the tributary Cypress Creek to its mouth at Hillsborough Bay is highly urbanized. Houses are located immediately on the river and in some cases are located in the ten-year flood plain. Urban stormwater drainage from the cities of Temple Terrace and Tampa is generally routed directly to the river, with little or no retention or quality control provided.

Water quality sampling efforts indicate that as the river passes through the urban areas, the water quality is degraded. Particularly important to the City of Tampa is the utilization of the Hillsborough River as a surface reservoir of raw water for potable uses. The Tampa water system pumps approximately 65 mgd of water from the reservoir and has a plant capacity of 94 mgd. The City of Tampa reservoir is formed by the City dam, located approximately at 30th Street. The reservoir water storage currently covers approximately 950 acres. The water treatment facility is located directly upstream from the dam.

The majority of the annual low flow of the river is diverted through the waterworks and consumed by the residents of the City. During the wet season, some water passes over the dam; however, the reservoir pool is usually maintained at approximately 22 m.s.l., resulting in the river segment below the dam being primarily tidal in nature.

Ten storm sewers of 60" or larger drain directly into the Tampa reservoir; numerous smaller storm sewers and urban sheet flows also enter the reservoir. Two industrial sources dicharge into the river at this point; McGraw Edison and Anheuser Busch both discharge cooling water. Several residential areas directly adjacent to the reservoir utilize onsite waste disposal systems (septic tanks), which in times of high ground water levels, may be discharging into the river.

The segment of the river below the dam exhibits characteristcs of a tidal stream, varying in width from about 50 feet near the dam to approximately 300 feet in downtown Tampa. Depth varies from a few inches to nineteen feet. Urban residential, commercial, and industrial uses border most of the river along this segment. The watershed below the dam consists of approximately 45 square miles, with urban land uses predominating. This river segment has the environmental characteristics of a low salinity estuary. Two river-miles downstream from Tampa dam is Sulphur Springs, with an average annual flow of 31 mgd. Usually the springs discharge directly into the river; however, during periods of low river flow, up to 20 mgd can be diverted upstream to the reservoir to be utilized as a potable supply augmentation. Several other small springs also discharge into the river in this segment.

This segment is also impacted by urban storm water runoff. At least 106 stormwater outfalls (24" and above the diameter) discharge into the river, draining almost one-third of the City. Because of the age of these systems and the urban development intensity, little or no structural quality control measures are incorporated. Both open ditch and closed systems are utilized. The river finally empties into Hillsborough Bay at downtown Tampa; the last 1.5 miles are maintained for commercial navigation.

Hillsborough Bay

The Hillsborough/McKay Bay systems are part of the larger Tampa Bay system, a complex series of estuaries on the west central coast of Florida. Hillsborough Bay is a natural arm of Tampa Bay, approximately eight miles long and four miles wide. McKay Bay is an extension of Hillsborough Bay. Hillsborough Bay has three major freshwater tributaries, the Hillsborough River, the Palm River, and the Alafia River. Improved channels are maintained at 34 foot depths. The surface area of Hillsborough Bay, including the harbor area, Port Sutton, and McKay Bay, is 39.6 square miles and the total volume is 8.3×10^9 cubic feet at mean low water. Shoreline slopes are gentle except at bulkheads, with the 6-foot depth contour extending some 400 yards off the western shore and about 1200 yards off the eastern shore. Bottom configuration has been altered markely by channel dredging and placement of spoil.

Tides are of the mixed type, having one strong flood and ebb per day with an intermediate phase which may be either flood or ebb. The diurnal tidal ranges is 2.8 feet and the mean level is 1.4 feet.

Several major dredge and fill projects have dramatically altered natural configuration of the Hillsborough/McKay Bay system. Davis Islands, situated in northern Hillsborough Bay, were dredged in the Florida land boom of the 1920's. Land use on Davis Islands is primarily residential, with a small commercial strip, a general aviation airport, and Tampa General Hospital. Seddon Island, directly east of Davis Islands, is currently undeveloped. Hooker's Point, a natural pensinsula, has been enlarged by dredging, and is the site of most of Tampa heavy industry and port terminals. Connecting Hooker Point with the eastern shore, and bisecting McKay Bay, is the 22nd Street Causeway. Port Sutton, on the eastern shore of Hillsborough Bay, is the site of several shipping terminals and an electrical generating plant.

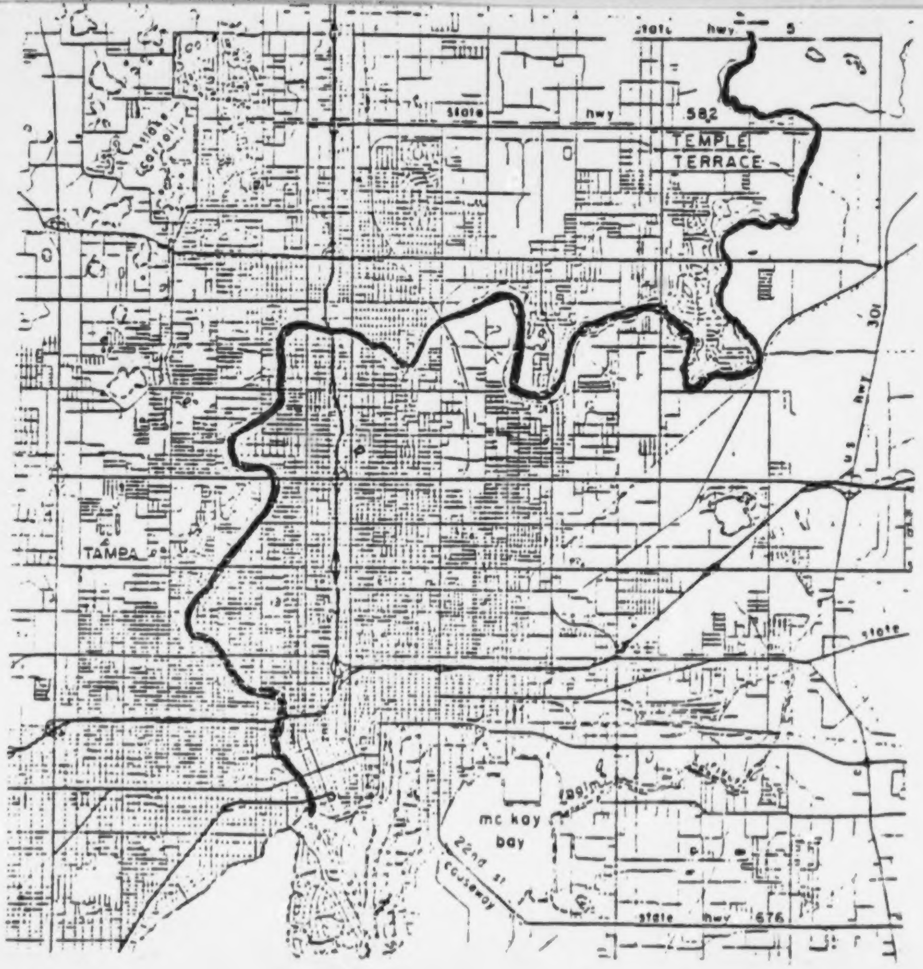
McKay Bay, named after former Tampa Mayor D.B. McKay, is a small shallow bay located at the northeast corner of Hillsborough Bay. Before extensive dredging and filling took place in Hillsborough Bay, there was no distinct dividing line separating it from the rest of Hillsborough Bay. However, after the construction of the 22nd Street Causeway and bridge in 1926-1927 and more recently the dredging and filling of Hooker Point and Port Sutton, McKay has become a distinct, isolated body of water.

The present shoreline is 7.5 miles long and covers 977.8 acres. The deepest natural depth for the bay is only 5 feet. However, a number of old borrow areas and the dredging of the Tampa Bypass Canal left areas as deep as 12-15 feet.

Freshwater discharges into the Hillsborough/McKay Bay systems originate from the three rivers, stormwater runoff from urban and rural sources, and point discharges from sewerage treatment plants. The Hillsborough River's mean annual discharge is 397 mgd in a natural state (bear in mind the diversion to the municipal waterworks). The maximum recorded natural flows have been significantly modified by the construction of the Tampa Bypass Canal. The canal, designed by the U.S. Army Corps of Engineers, is being constructed to prevent the flooding of the Hillsborough River. Flood surges can be diverted from the Hillsborough River to the bypass through a series of canals and control structures. The canal extends partially into the Floridan aquifer, and acts as a collector for groundwater discharges. Estimates vary as to the amount of groundwater entering the canal, the most recent estimate is between 15 to 25 mgd. The figure for groundwater discharges, added to the natural flow of the Palm River, yields an estimate of 90 mgd mean annual discharge.

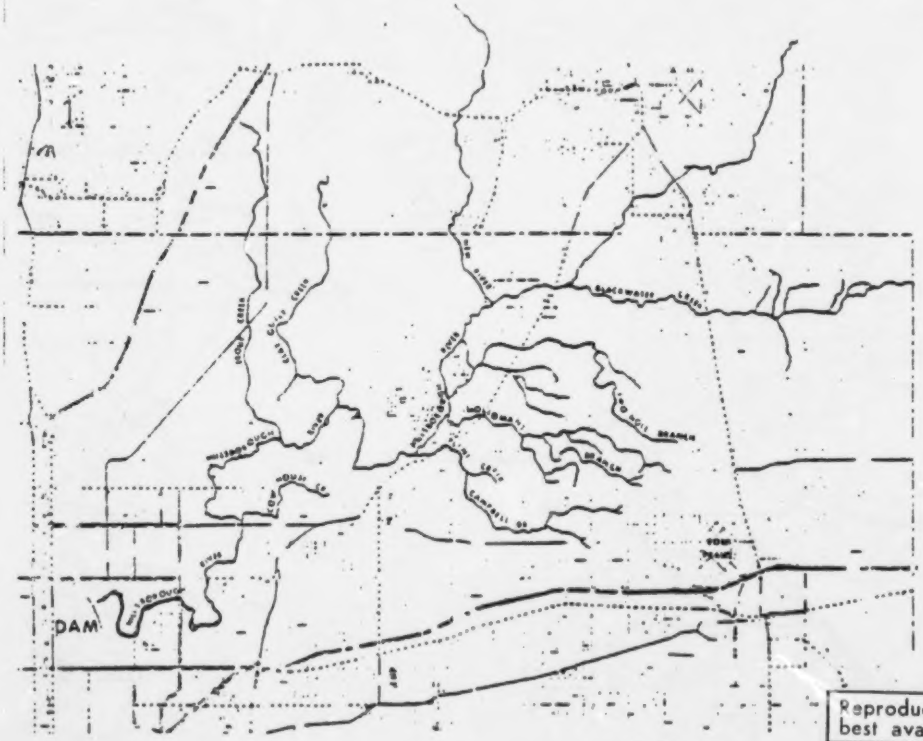
The Alafia River drains approximately 460 square miles of Hillsborough and Polk Counties. No significant man-induced changes are present to modify natural flows. The average annual discharge is 264 mgd, with a maximum of 1,118 mgd and a minimum of 4.3 .

Stormwater runoff enters the Bay through closed urban systems, open urban systems, open rural systems, and natural sheet flow.



URBAN SEGMENTS
HILLSBOROUGH RIVER

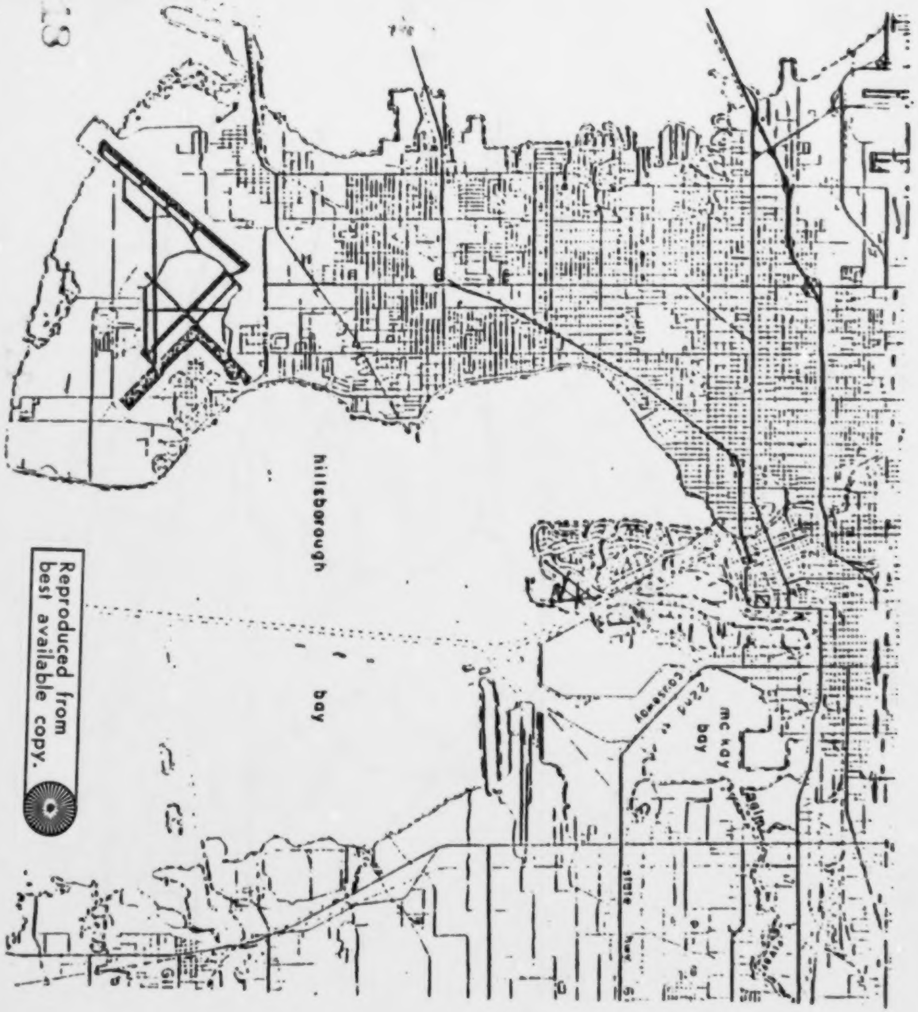
411-13



411-12

RURAL SEGMENT
HILLSBOROUGH RIVER

Reproduced from best available copy.



Reproduced from
best available copy.

Hillsborough/
McKay Bay System

PROJECT AREA

Sites have not been selected for the Tampa NURP project yet. Therefore, fixed site data is not available.

PROBLEM

A. Local Definition

The Hillsborough River/Hillsborough Bay System quality has declined to the extent that many of its beneficial uses are now impossible. The most recent general water quality index for body contact by the Hillsborough County Environmental Protection Commission rated Hillsborough Bay as undesirable for any form of body contact. A once significant shellfish industry estimated in 1969 to be valued at $1.5 million, is now gone. Aesthetically, enjoyment of the river and bay led to the development of desirable residential areas along the waterfront. Odor, color, turbidity, and bacterial contamination have reduced the benefits of the Bay. Sporadic fish kills compound the problem.

Several incidents and low water quality in general, have resulted in water quality below minimum state standards. Point sources, urban and rural runoff, natural background, and the dredge and fill activities all contribute to the problem.

The City of Tampa utilizes the Hillsborough River as a potable water supply. State water quality standards are the highest for such potable water bodies. Urbanization has, however, extensively impacted this segment of the Hillsborough River. Two cities, Tampa and Temple Terrace route urban stormwater into the reservoir segment. The City of Tampa alone has eleven outfalls, 24 inches or larger, discharging into the Reservoir. Water quality problems are further compounded by upstream rural runoff from agricultural lands, and large blooms of water hyacinths in the reservoir. Runoff adds nutrients, suspended solids, and coliform bacteria to the water supply; water hyacinths add to the nutrient problem, and upon their death, contribute to a low dissolved oxygen problem. Runoff from a large development bordering on the Hillsborough River north of Temple Terrace will probably have to be treated to at least maintain present water quality of the reservoir.

B. Local Perception

Several studies were undertaken over the past few years to evaluate the conditions of the Hillsborough River and Bay. There is a tremendous interest on the part of local professors, local USGS offices and the Public Works Department to define the problem.

The USGS established a stormwater evaluation program in 1974. That project established 10 streamflow gaging stations, 12 recording rain gages and tabulated watershed land uses. Runoff and rainfall data, and water quality data, has been collected since 1975.

The University of South Florida, College of Engineering, has performed several hydraulic and hydrologic studies in an attempt to develop models to simulate the hydraulics of the Bay.

The Public Works Department is concerned with the quantity as well as quality problems. Tampa's relative lack of significant topographical relief, coupled with a high average annual rainfall, has necessitated the construction of numerous storm sewer systems. The majority of the systems were constructed well before urban runoff was considered to be a possible source of water quality problems. The City of Tampa has identified over 300 drainage problem areas and is concerned with taking care of these yet satisfying the State standards.

PROJECT DESCRIPTION

A. Major Objective

Goals of the Tampa urban runoff studies are to characterize the stormwater flows and loads *from urban drainage basins*, analyze the effectiveness of selected stormwater controls, determine the impact of storm *generated loads* on the lower Hillsborough River and develop a stormwater management plan for the City of Tampa. The stormwater management plan will address receiving water quality, the quantity and quality aspects of stormwater runoff, and support the cities efforts to deal with flooding problems in an environmentally sound manner.

B. Methodologies

Rainfall quantity and quality data will be collected and analyzed to develop design storms and storm sequences, and characterize the direct load input to the drainage basins from rainfall. Basins will be selected for detailed monitoring during storm events to assess rainfall-runoff relationships and stormwater flows and loads. Stormwater controls will be selected and monitored during storm events to assess their effectiveness in reducing stormwater loadings. Stormwater flows and loads will be determined for the entire study area under design conditions and used in development of the citywide stormwater management plan.

A receiving water study will be on-going concurrently, funded by the City of Tampa. This study will consist of a data collection effort intended to better characterize water quality in the lower Hillsborough River and analysis of these data to determine the impact of stormwater runoff. Specifically, the data collection effort will consist of continuous monitoring of stage, temperature, conductivity and dissolved oxygen, synoptic sampling conducted during distinct hydrologic conditions, continued collection of long-term background data, collection of sediment oxygen demand and sediment chemistry data, and biological sampling.

C. Monitoring

Equipment is just being ordered. It is anticipated that each site will contain a precipitation recorder and sampler, a water level recorder and an automatic sampler.

D. Controls

Controls to be monitored have not been definitely selected. The controls studied may include 1) detention/retention basin with underdrain, 2) drainfield or trench, 3) open bottom inlet or catchbasin and 4) undercut ditch.

NATIONWIDE URBAN RUNOFF PROGRAM

KNOXVILLE/KNOX COUNTY METROPOLITAN PLANNING COMMISSION

KNOXVILLE, TN

REGION IV, EPA

INTRODUCTION

Knoxville, Tennessee is a growing metropolitan area with a population of some 182,000 persons living within the present city limits. Total Knox County population is approximately 335,000, while some 483,000 persons live within the SMSA.

An earlier study of some urban streams in Knoxville revealed that urbanization has a greater than expected effect on the hydrological regimes of streams with large amounts of carbonate rocks in the basin. Under rural conditions much of the streamflow is lost to the carbonate rocks and solution channels and is not measured as surface runoff. Land cover alterations, along with sewers and channel modifications in the study watersheds, resulted in an increase in the peak of the unit hydrograph of from 1.9 to 3.6 times and a decrease in time to peak ranging from .86 to .36.

An important conclusion of the previous study was the recognized need for additional water quality monitoring across the flow regime. Building on this original data base, the Second Creek basin is being studied. Second Creek while typical of other urban streams in the area, is well recognized for its poor water quality. The Knoxville Metropolitan Commission and Tennessee Valley Authority hope to identify the cause of these water quality problems and the solutions.

PHYSICAL DESCRIPTION

A. Area

Knox County, located in eastern Tennessee, lies wholly within the Ridge and Valley physiographic province of the southern Appalachian region, extending from 35°47'30"N. to 36°10'30"N. latitude, and 83°39'W. to 84°16'W. longitude.

The topography of the county consists of alternating ridges and valleys which cut into the steeply dipping, folded and faulted calcareous rocks. The rocks include limestone, dolomite, calcareous shale, sandstone, and sandy shale.

Most soils have textures ranging from loam to silty clay loam. Depth to bedrock ranges from zero to more that 20 feet. Fifty-seven percent of the county has a soil depth of more than five feet.

The study area is located in a broad valley between the Cumberland mountains and the Great Smoky Mountains. These two mountain ranges have a significant influence upon the climate of the valley. Topography has a pronounced effect upon the prevailing wind direction. Winds usually have a southwesterly component during day time, while night time winds usually move from the northeast.

Rainfall is distributed throughout the year with a normal annual total of 47.98 inches.

B. Population

The population of Knox County has grown significantly in the past 15 years. Between 1960 and 1970 the county grew 10.3%, while between 1970 and 1975 it grew 9.8%. Between 1975 and 1990 the county is projected to grow an additional 23.7%. The following table shows the population of the county.

Year	Population
1960	250,523
1970	276,293
1975	303,900
1980	335,400

C. Drainage

There are five drainage basins within the Knoxville-Knox County study area which, by nature of their land use, may be considered urban. These include First Creek, Second Creek, Third Creek, Fourth Creek, and Ten Mile Creek. The two most intensely developed drainage basins, First Creek and Second Creek, were chosen for this study. In combination, these two creeks drain the entire Knoxville central business district.

First Creek Drainage Basin

The First Creek drainage basin encompasses an area of 22.04 square miles, the largest in the Knoxville metropolitan area. Seventeen percent of the area (3.78 square miles) drains into sinkholes. These sinkhole areas are primarily in the north and northwest parts of the basin. The average drainage density of the First Creek basin is nine miles of channel per square mile, with the highest drainage density on steep slopes and less soluble geographic formations, and lowest drainage density on gentle slopes and more soluble rocks.

Groundwater elevation and permanent streams in the First Creek drainage basin are shown on Figures 1 and 2. The major trunk of First Creek runs from northwest to southeast and intercepts northeast - southwest surface and groundwater flows. Inter - basin water transfer may occur where abundant sinkholes are present and the surface drainage divide is not prominent.

In the First Creek drainage basin, commercial land use is concentrated on the lower (downstream) portions of the basin and along the Broadway strip commercial development. Open and forest lands predominate in the northeastern portions of the basin. Although industrial and multi-family land uses cover small portions of the basin, single family residential land use is important. Table 1 shows the percentage of different land uses in the basin.

Areas of potentially high water yield are associated with steep slopes, high elevations, shallow and less permeable soils (low soil moisture capacity), shale bedrock, faults acting as groundwater barriers, and densely developed residential and commercial land uses which have a large percentage of impervious surfaces. Areas of potentially low water yield are related to deep and more permeable soils, gentle slopes, and carbonate rocks where bypass losses of groundwater occur, especially in summer and fall when soil moisture is depleted. In general low water yield occurs in summer and fall on relatively low elevations, deep and more permeable soils, carbonate rocks, and open and forested areas.

Second Creek Drainage Basin

The Second Creek watershed is adjoined on the east by the First Creek basin and on the west by Third Creek basin. Second Creek basin is elongated in shape and is the smallest major drainage basin in the Knoxville urban area. The creek originates on Blackoak Ridge north of Inskip and Norwood communities and drains into a gently rolling area. It has no major tributaries unlike the other principal streams in Knoxville. The creek flows into central Knoxville through the gap in Sharps Ridge where I-75 (U.S. Highway 25W) and the Southern Railway pass through. Below the gap it passes the Southern Railway's Coster Yards and is repeatedly crossed by the railway before reaching downtown Knoxville. The creek enters the Tennessee River at the eastern edge of the campus of the University of Tennessee.

The basin has a drainage area of 7.1 square miles (4,544 acres) including an area 0.5 square miles (320 acres) that drains into sinkholes and has no surface channels. The complete drainage basin is shown on Figure 3. Drainage density is high on steep slopes and high-elevation areas, while low drainage density is associated

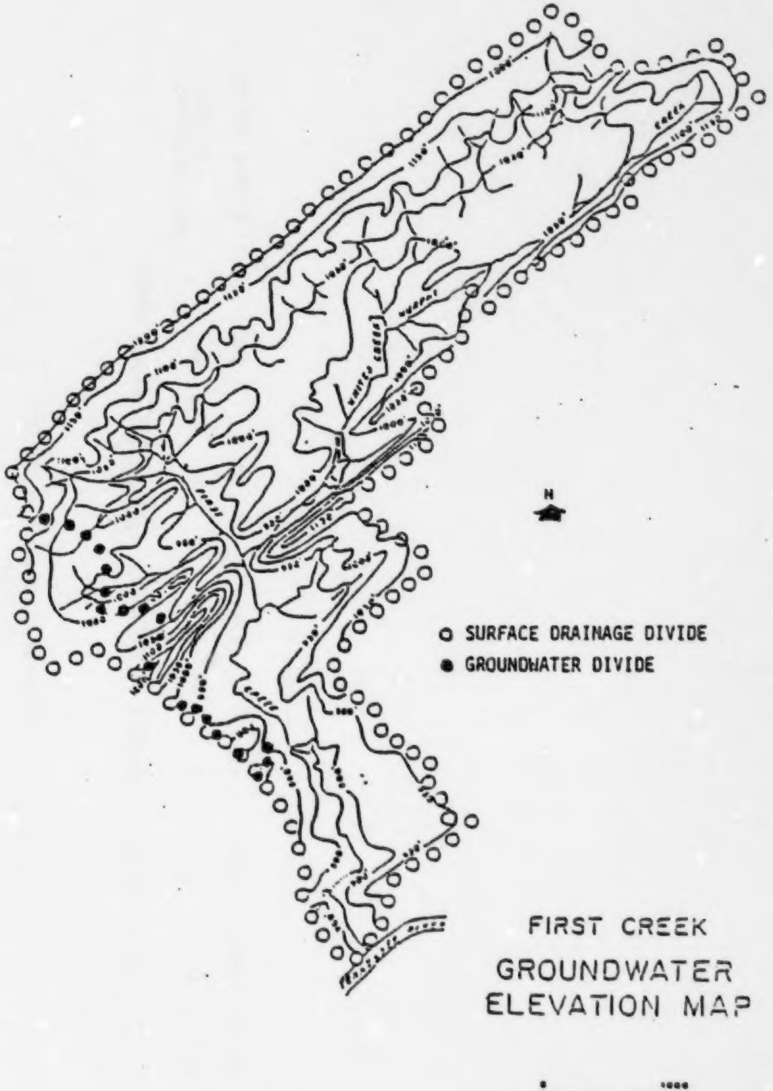


Figure 1

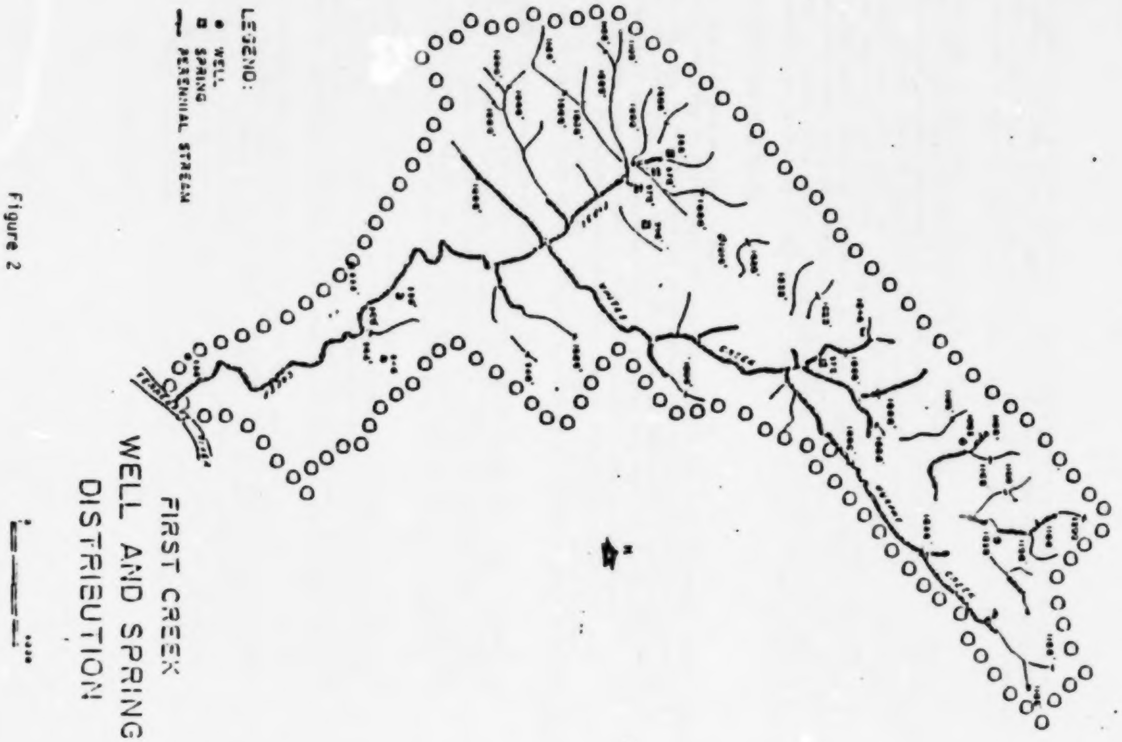
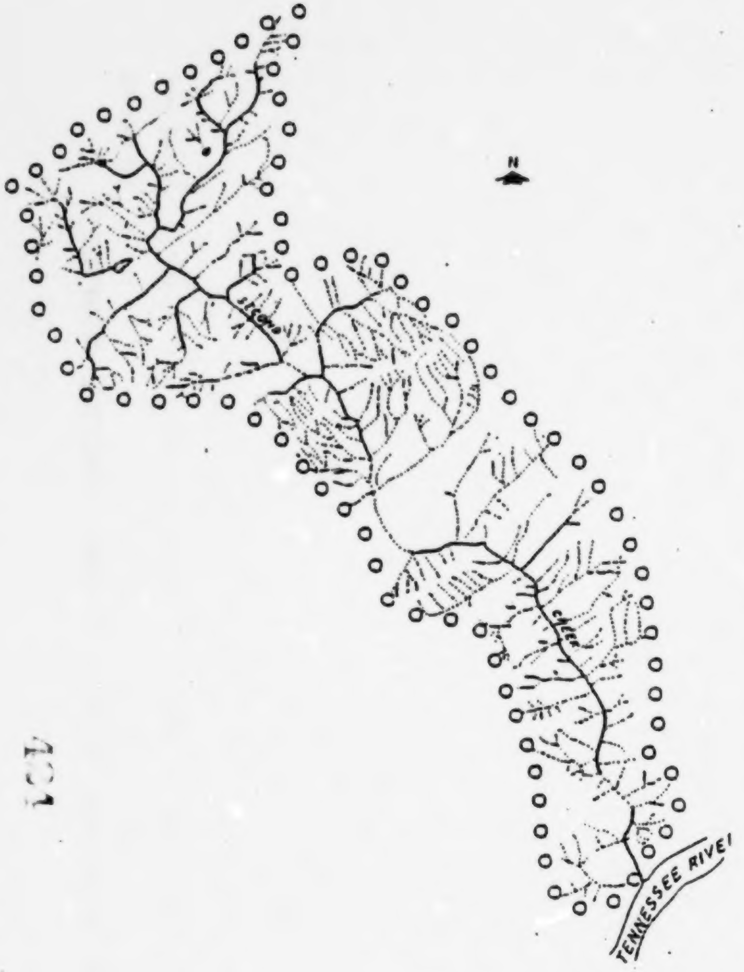


Figure 2

TABLE 1

LAND USE IN FIRST CREEK DRAINAGE BASIN

	Single Family	Multi-Family	Commercial	Industrial	Open	Forest	Total	Total Imperviou
Percent of total area (%)	45	6	6	1	28	14	100	17.5
Extent (Acres)	6,347	846	846	141	3,949	1,975	14,104	2,468



SECOND CREEK

DRAINAGE NETWOR

Figure 3

with gentle slopes and low-elevation areas such as the Coster railway yard. The highest drainage density ocurs on Sharps Ridge, where the geologic structure is complex, rocks are impermeable and not highly soluble, elevation is high, and slopes are steep.

Elevations in Second Creek basin range mostly between 900 and 1,100 feet. The maximum elevations are 1,360 feet on Blackoak Ridge and 1,400 feet on Sharps Ridge, both on the divide between First and Second Creeks. Along the divide between Second and Third Creeks, the maximum elevations are 1,180 feet on Blackoak Ridge and 1,340 feet on Sharps Ridge. The lowest elevation in the basin at the mouth of Second Creek is 810 feet. The local relief is 590 feet.

Second Creek basin is more urbanized than First Creek. Commercial developments are located downtown, along Central Avenue, and along Clinton Highway. Industrial use is extensive from Western Avenue to the Coster yards of the Southern Railway. Because of the greater extent of industrial land and less open and forested lands than in the First Creek basin, a higher percentage of impervious surfaces and higher water yield occurs. Table 2 indicates the percentage of different land uses in the basin.

D. Sewerage System

Storm sewers are used primarily to convey water to the nearest surface stream. A few older homes have septic tanks, the remainder are served by sanitary sewers.

TABLE 2

PERCENTAGE OF LAND USE IN SECOND CREEK DRAINAGE BASIN

	Single Family	Multi-Family	Commercial	Industrial	Open	Forest	Total	Total Impervious
Percent (%)	54	8	12	8	11	7	100	26
Size (Acres)	2,454	364	545	364	499	318	4,544	1,181

PROJECT AREA

I. Catchment Name - R1 (Residential Site One)

A. Area - 54.24 acres.

B. Population - 578 persons.

C. Drainage - End-of-pipe site draining residential land use. Main channel is 1600 feet.

D. Sewerage - Drainage area of catchment is 89.92% separate storm sewers. 81.92% of this area has curbs and gutters and 18.06% has swales and ditches. 10.08% is not served by separate storm sewers.

E. Land Use

46.17 acres (85%) is 2.5 to 8 dwelling units per acre residential.

4.04 acres (7%) is urban institutional.

1.41 acres (3%) is urban parkland.

2.62 acres (5%) is linear strip development.

II. Catchment Name - SC (Strip Commercial Site)

A. Area - 187.04 acres.

B. Population - 464 persons.

C. Drainage - Drainage ditch draining strip commercial site. Main channel is 1330 feet.

D. Sewerage - Drainage area of catchment is 23.47% separate storm sewers. 100% of this area has curbs and gutters. 76.53% of the area does not have separate storm sewers.

E. Land Use

1.08 acres (1%) is urban institutional.

65.40 acres (35%) is linear strip development.

101.02 acres (54%) is .5 to 2 dwelling units per acre residential.

18.8 acres (10%) is < 5 dwelling units per acre.

.70 acres (<1%) is 2.5 to 8 dwelling units per acre.

III. Catchment Name - RS2 (Residential Site Two)

- A. Area - 89.34 acres.
- B. Population - 333 persons.
- C. Drainage - End-of-pipe site draining residential land use. Main channel is 1600 feet.
- D. Sewerage - 100% of the area has no separate storm sewers.
- E. Land Use

66.40 acres (74%) is .5 to 2 dwelling units per acre.

3.40 acres (4%) is linear strip development.

.70 acres (1%) is 2.5 to 8 dwelling units per acre residential.

18.8 acres (21%) is < .5 to dwelling units per acre residential.

IV. Catchment Name - CBD (Central Business District)

- A. Area - 25.8 acres.
- B. Population - 0 persons.
- C. Drainage - End-of-pipe site draining central business district.
- D. Sewerage - 100% of the area is served by separate storm sewers. 100% of that area has curbs and gutters.
- E. Land Use

25.8 acres (100%) is Central Business District.

PROBLEM

A. Local Definition

An earlier study of some urban streams in Knoxville revealed that urbanization has a greater than expected effect on the hydrological regimes of streams with large amounts of carbonate rocks in the basin. Under rural conditions much of the streamflow is lost to the carbonate rocks and solution channels and is not measured as surface runoff. Land cover alterations, along with sewers and channel modifications in the study watersheds, resulted in an increase in the peak of the unit hydrograph of from 1.9 to 3.6 times and a decrease in time to peak ranging from 0.86 to 0.36. From a water quality standpoint, material transport of most constituents from the basins was not significantly greater than that which has been previously reported for some rural watersheds.

This Knoxville, Tennessee urban study was conducted at four watersheds located in Karst terrain - - areas overlying soluble carbonate rock. Storm sewers are used in these study watersheds to convey stormwaters to the nearest channel. As a consequence, the hydrology of these study catchments proved to be quite complex which served to provide some contrasts for evaluating and quantifying these urban systems.

Mathematical streamflow models which had been developed earlier using data from typical rural areas were modified to handle urban watersheds and used in this study to quantify the impact of urbanization upon the hydrology of the study watersheds. The models were regionalized so that necessary parameters could be predicted from watershed and climatic measures.

Based upon the model studies, urbanization was found to have a particularly marked effect on water yield from catchments where, under rural conditions, most of the potential streamflow is lost to the carbonate rock drainage system. Increases in yield up to 270 percent were found in a watershed where development is extensive. Most of this increase results from storm runoff that under rural conditions would have drained into the carbonate rock system and therefore bypassed the gage site. At one watershed where bypass losses were not a factor, modest increases in stormwater runoff resulted in a near-corresponding decrease in groundwater runoff.

In the study, it was found that urbanization can affect the storm hydrograph in two ways. Through land cover alternations along with sewers and channel changes, the peak of the unit hydrograph was found to have been increased at the study watersheds by factors ranging from 1.9 to 3.6. The times to peak were decreased by factors ranging from .86 to .36. Increased storm runoff from urbanization, it was found, could further modify the unit hydrograph.

Bulk precipitation and water quality data collected at the project were compared with data collected at other studies. It was found that because much of the potential runoff at two of the project watersheds was lost to the carbonate rock drainage system these watersheds act as filters. For most constituents the loadings into the watersheds from the atmosphere exceeded the streamflow loadings

The concentrations and loadings of some metals were found to be well in excess of recommended water quality criteria in two of the project watersheds. High values for iron and manganese that were found appeared to be associated with erosion problems. Relatively high concentrations of lead were also found and the source appeared to be the atmosphere.

The streamflow loadings of organics and the concentrations of pathogenic indicators were found to be high from the study areas and reasonably comparable with urban data collected elsewhere.

The most important conclusions from this study were the following:

1) The impact of urbanization upon the storm hydrograph results from a combination of land use/channel drainage changes and storm runoff changes

2) Atmospheric sources may account for most of the loadings for many water quality constituents, at least in watersheds with separate sewer systems

3) There is a need for monitoring of water quality. Water quality in rural and urban areas should be monitored across the flow regime in order to be used in the development of operational nonpoint source water quality models and identify pollution source information so that pollution control money will be spent effectively and result in the greatest improvement in water quality.

B. Local perception

The water quality problems typically found in Knoxville's urban streams can be appreciated by the following general observation of conditions in Second Creek. Portions of Second Creek are highly eutrophic -- there are stream reaches measured in hundreds of yards where the water surface is totally obscured by rooted vegetation. In other areas the stream is replete with filamentations and other types of algae and a host of slimes. Evidence of streambank erosion due to increased runoff rates is abundant. During storm events, the stream may turn absolutely black as it passes through the lower central business district, and it produces a visible plume at its confluence point with the Tennesse River that can last for many hours after a storm event and extend downstream for a considerable distance.

The harshest indictment of Second Creek's present water quality has arisen in conjunction with the planned 1982 International Energy Exposition which Knoxville will host. The six-month long event will occupy a site at the lower end of the Second Creek basin, and initial plans were to integrate the creek into the site design. Residual plans for the Exposition site include a public park with a flow through pond on Second Creek to serve as a focal point. The degraded water quality of Second Creek is so poor (including such aesthetically important considerations for a park as color and odor) that Expo planners are considering ways to hide the creek from attenders and are drilling wells as a source for water to maintain the pond during the course of the Exposition. Such an energy and other resource intensive alternative can hardly be considered as a BMP or long-term solution to park maintenance. Of even greater concern is the fact that the creek constitutes such a public health menace due to the bacterial contamination (State standards can be exceeded by many orders of magnitude during and after a storm) that unless some remedial action is taken, it will be necessary to exert physical barriers to prevent even partial body contact.

The Tennessee River is actually the backwater of Fort Loudoun Reservoir as it passes through Knoxville and is used as a drinking water source by downstream communities (as well as Knoxville) in addition to such recreational activities as swimming, boating, fishing, etc. Although a single urban stream such as Second Creek probably does not exert a severe impact on the river in and of itself, the accumulated discharges of all of Knoxville's urban streams may well exert considerable stress on the assimilative capacity of the river and contribute to its degrading water quality. Although it will remain for the NURP project to provide firm quantification of these urban runoff loads, it is conjectured that their combined loading might well be an order of magnitude greater than that of the sewage treatment plant when its upgrading is finished in 1982. Should this prove to be the case, the need for better water quality management practices will be even more acute since the affected receiving water will include the reservoir as well as the urban streams themselves.

PROJECT DESCRIPTION

A. Major Objective

The purpose of the proposed project in Knoxville is to examine the water quality problems which result from man's urban activities and to determine what management practices might be implemented to mitigate the present water quality problems and prevent others from occurring as the area of urban development expands. The major objectives are the following:

1) Determine sources of pollutants in urban streams that result from storm events and threaten, impact or deny their designated beneficial uses.

2) To further characterize the urban stream systems.

3) To provide increased confidence in the transfer of data from gaged to ungaged catchments at the local, State, Regional, and National levels.

4) To provide a better understanding of the influence of the geological features (karst terrain, carbonate rock) on urban runoff.

5) To provide preliminary data on BMP effectiveness at a pilot scale level.

The primary emphasis of the project is on the Second Creek basin, although a small catchment located in the First Creek basin is included to help establish the transferability of the data.

B. Methodologies

An intense data collection effort will take place over a two year period to further characterize the urban runoff loads and the impact on the stream. The source of the pollutants, their concentrations, and transport, and their relationship to the runoff process will be described.

C. Monitoring

Six sampling sites are included in the study. These sites cover different land uses as well as attempt to characterize the karst terrain. Following is a brief description of the equipment available at each of the sites listed.

Central Business District Site
Residential (Woodland Ave.)
Upper Sink
Lower Sink
Residential (Orchid Drive)
Strip Commercial

Central Business District Site

The CBD sampling site is located at the intersection of Central Street and Union Avenue. Water sampling and flow measurement is performed in the outflow pipe of a manhole. A 30 inch Palmer-Bowlus flume is installed in the outflow pipe. An ISCO model 1870 flow meter is used in conjunction with the flume to measure and record flow. Flow proportional water samples are collected during rain events with an ISCO model 2100 automatic water sampler. A wet/dry atmospheric collector as well as a recording raingage are located at the site.

Woodland Avenue Residential Site

This sampling site is located near Woodland Avenue and Central Street. The sampling is done in a drainage ditch tributary to Second Creek. A 48 inch Palmer-Bowlus flume has been installed in the ditch. An ISCO model 1700 flow meter will be used to measure the flow going through the flume. The totalized flow values are recorded by an ISCO model 1710 digital printer. A Friez water level recorder will be used to obtain a continuous strip chart record of the flow. Flow proportional water samples are collected by an ISCO model 2100 automatic water sampler. A recording raingage and wet/dry atmospheric collector are located at a residence adjacent to the sampling location.

Lower Sink Site

The lower sink site is located just off Rowan Drive in a drainage ditch tributary to Second Creek. The data collected at this site is limited to flow data. The primary flow measuring device is a concrete control structure plus a weir plate. A rating curve is being developed for the control structure. A Friez water level recorder is used to acquire a complete set of flow data. The site, which is in a sink area, will be studied (using tracers) in conjunction with the upper sink site to accumulate data regarding subsurface drainage in the area of karst-terrain. A raingage is located within the drainage area.

Upper Sink Site

The upper sink site is located on Sanford Road, approximately two blocks north of the lower sink site. The data collection at this site is also limited to flow data. The data collected at this site will be used in conjunction with the data collected at the lower sink site to study subsurface drainage. The equipment is the same at the two sites.

Orchid Drive Residential Site

The Orchid Drive site is located in a culvert next to the Midas Muffler Shop. The primary flow measuring device is a 30 inch Palmer-Bowlus flume. An ISCO model 1700 flow meter is used to measure flow. The total flow values are recorded by an ISCO model 1710 digital printer. A modified Friez water level recorder is used to obtain a continuous strip chart record of the flow. Flow proportional water samples are collected with an ISCO model 2100 automatic water sampler. A recording raingage and wet/dry atomospheric collector are located in the upper part of this drainage area.

Strip Commercial Site

The strip commercial site is located in a drainage ditch behind the Clinton Plaza Shopping Center.

A 54 inch Palmer-Bowlus flume is installed in the ditch. An ISCO model 1700 flow meter is used to measure the flow going through the flume. An ISCO model 1710 digital printer records total flow values and a modified Friez water level recorder provides a continuous strip chart record of the flow. A recording raingage and wet/dry atmospheric collector is located in the drainage area. Flow proportional water samples are collected by an ISCO model 2100 automatic water sampler.

Tennessee Valley Authority is responsible for most of the technical work, including sampling equipment installation and calibration, data collection, and sample and data analysis. Both composite and discrete samples will be taken. It is hoped that composite samples will be collected from 16 storm and discrete samples from 8 storms.

D. Controls

The Best Management Practices which will be evaluated have not yet been determined. After preliminary sampling results are obtained, BMP's will be selected and implemented at the various sites in order to evaluate their effectiveness.

NATIONWIDE URBAN RUNOFF PROGRAM

TRI-COUNTY REGIONAL PLANNING COMMISSION

LANSING, MI

REGION V, EPA

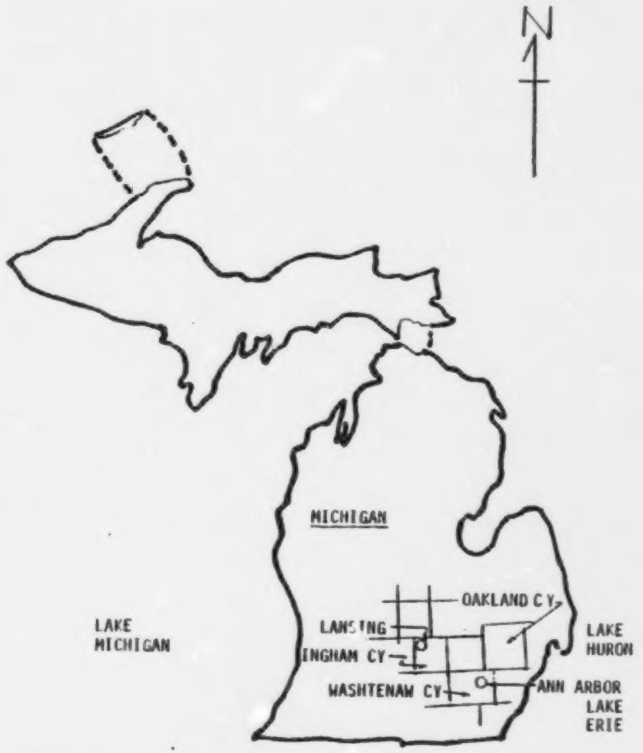
INTRODUCTION

This project, with investigation conducted under the direction of the Tri-County Regional Planning Commission, is located in the City of Lansing state capital of Michigan. Urban stormwater pollution impacts are being evaluated in the Bogus Swamp Drainage District, Ingham County, which is drained by storm sewers into the Grand River. The Grand River and its major tributaries in the vicinity of Lansing, the Red Cedar and Sycamore River, flow eventually into Lake Michigan.

The Grand River has been classified for total body contact recreation in the reach into which the Bogus Swamp stormdrain network flows. Future planning for the Grand River includes fish ladders to allow fish migration, and development of linear parks, some of which already exist along the river, which is now used for boating and fishing, with other recreation activities conducted primarily at lake Lansing.

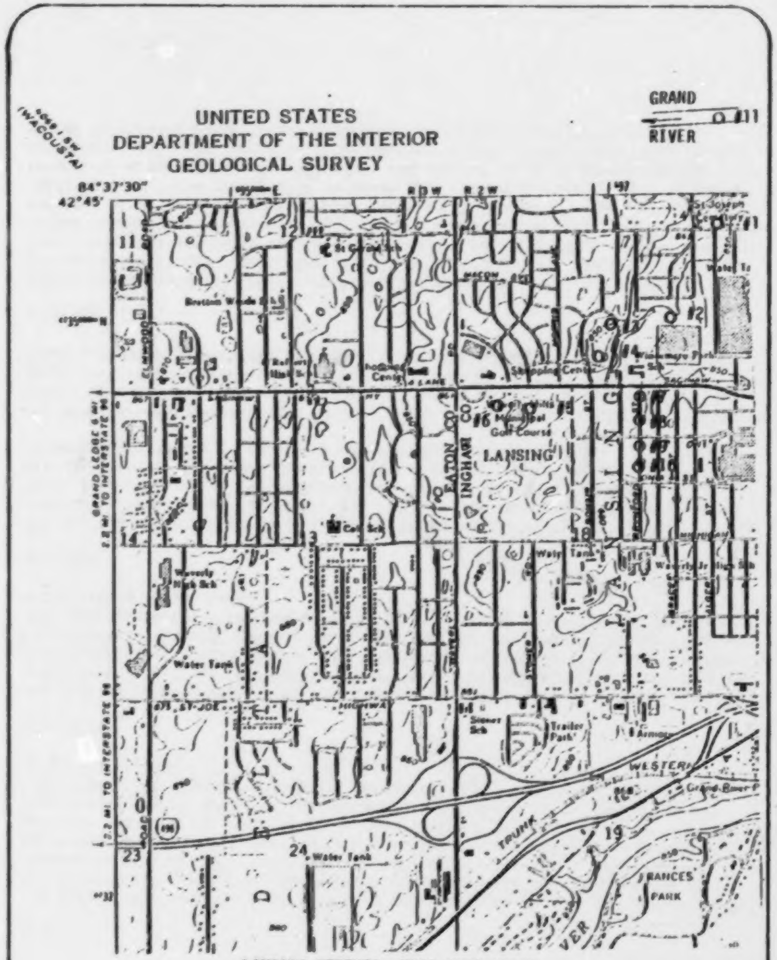
The existing water quality of the Grand River was documented in recent monitoring efforts. Problems were identified as the result of (1) point source discharges; (2) combined sewer overflows; and (3) stormwater drainage. Nonpoint source pollution has been identified as a major contributor to biochemical oxygen demand, nitrogen and suspended solids.

Of concern to the local and regional agencies is the need to evaluate the effectiveness of best management practices that may be applied to reduce pollution of the Grand River. This information will be utilized in future planning for the most cost-effective total effort to reduce pollution from the three identified sources. Such future planning will also utilize similar data developed by other urban runoff projects underway nationwide to the extent it proves both transferrable and applicable. The project has the major objective of evaluating an in-line wet storage basin, a normally-dry detention basin, and two sections of increased diameter storm drains, for both costs and stormwater quality enhancement.



STATE LOCUS
MICHIGAN NURP PROJECTS

FIGURE 1



LANSING STREETS, USGS QUAD SHEET
SAMPLING AND MONITORING POINTS

FIGURE 2

Station Description and Schedule

Located in the Bogus Swamp Drain District are three types of Best Management Practices (BMP's) for the control of stormwater pollution. These are (a) two in-line upsized tiles, (b) an in-line retention basin, and (c) an off-line detention basin. Figure 1 illustrates monitoring stations and the "Best Management Practices" (BMP's) being studied and includes all station locations and designations in Table I. Each will be monitored for flow and stormwater constituents to determine the efficiency and cost effectiveness for the reduction of various pollutants. Sampling at the inlet and outlet of each BMP will require a total of ten stations, each consisting of flow recorders and samplers.

TABLE I. STATION DESCRIPTION

Station No.	and Location	BMP Type
1	Main Outlet	
2	West Subdistrict Drain	
	Dryer Farms	Detention Pond
3	- outlet	
4	- inlet	
	Golf Course Pond	Retention Pond
5	- outlet	
6	- inlet	
	Upsized tile	96" Sump
7	- outlet	
8	- inlet	
	Upsized tile	96" Sump
9	- outlet	
10	- inlet	
11	River	

PHYSICAL DESCRIPTION

A. Area

The City of Lansing Michigan, in Ingham County, is located in the north central lower peninsula. The Bogus Swamp Drain Drainage District, in which the best management pratices are installed, is west of, contiguous to, and representative of developed urban conditions in Lansing. The drainage district contains 450 acres. Land uses and land covers in this district are separated into more or less homogeneous covers which correspond to drainage subdistricts. Uses include single and multi-family residential, commercial, and industrial, as well as open space-recreation.

B. Population

The 1971 population of Lansing-East Lansing was 385,694, with a projected 1980 population (Series E, 1972 OBERS) of 434,000. The 1980 census for the Lansing SMSA reported an actual population of 468,482, and 130,414 within the Lansing city limits. The 1972 OBERS projection shows that the 1980 SMSA population was not anticipated to be reached until 1985, which is an indication of the rate of urbanization in the area.

C. Drainage

The drainage district terrain is typical Michigan glacial landscape with gently rolling topography and relatively low slopes. The surface elevation drops 20 feet, from 890 feet at the headwaters to 870 feet at the Grand River outlet. Urbanization has increased the impervious cover to the extent that the capacity of many storm sewers is routinely exceeded by stormwater flows.

The Grand River headwaters are located south of Lansing, and with its tributaries drains approximately 2/3 -3/4 of Jackson County, most of Ingham County, and a small part of Eaton County on its way north through Lansing. From there it flows generally West-northwest until it enters Lake Michigan in Ottawa County.

D. Sewerage System

Within the drainage district, the storm and sanitary sewers are separate, except for possible illegal connections not yet detected. Within the City of Lansing, there are areas served by combined sewers which result in high levels of coliform in the Grand River, preventing body contact recreational uses. Correction of the combined sewer overflow problem will be incorporated into a combined total pollution reduction effort that includes application of best management practices to control urban stormwater pollution, and control of point source discharges, in the most effective manner. Such planning will be accomplished when results of the Nationwide Urban Runoff Program projects become available.

PROJECT AREA

I. Catchment Name - MI 1,001, Bogus Swamp Drain

A. Area - 452.6 acres

B. Population - 2250 persons.

C. *Drainage - Subsurface conveyance to the Grand River.* Main channel is 49,500 feet at a slope of approximately 32 feet per mile.

D. Sewerage - Drainage area of catchment is 100% separate storm sewers. Forty-nine percent is served by curbs and gutters, and 51% is served by swales and ditches.

E. Land Use

126.5 acres (28%) is 0.5 to 2 dwelling units per acre urban residential, of which 37.4 acres (30%) is impervious.

76.9 acres (17%) is 2.5 to 8 dwelling units per acre urban residential, of which 23.4 acres (30%) is impervious.

14.3 acres (3%) is > 8 dwelling units per acre urban residential, of which 8.3 acres (58%) is impervious.

13.2 acres (2.9%) is Linear Strip Development, of which 10.1 acres (78%) is impervious.

10.1 acres (2.2%) is Shopping Center, of which 10.1 acres (100%) is impervious.

3.3 acres (0.7%) is Urban Industrial (light), of which 2.2 acres (67%) is impervious.

83.2 acres (18.4%) is Urban Industrial (heavy), of wich 52.7 (63%) is impervious.

91 acres (20.1%) is Urban Parkland or Open Space, of which 5.6 acres (6%) is impervious.

Approximately 37% imperviousness in entire catchment area.

II. Catchment Name - MI 1,002, Bogus Swamp Drain

A. Area - 63 acres.

B. Population - 0 persons (industrial).

C. Drainage - This catchment area has a representative catchment slope of 132 feet/mile, and 100% curbs and gutters. The storm sewers approximate a 31 feet/mile slope, and extend 9,450 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers, and is completely provided with curbs and gutters.

Streets consist of 17 lane miles of asphalt all in fair condition and 2.2 lane miles of concrete, all in good condition.

E. Land Use

63 acres (100%) is Urban Industrial (heavy), of which 40.4 (64%) is impervious.

III. Catchment Name - MI 1,DRO, Bogus Swamp Drain

A. Area - 127.6 acres.

B. Population - 550 persons.

C. Drainage - This catchment area has a representative slope of 121 feet/mile, 37% served with curbs and gutters and 63% served with swales and ditches. The storm sewers approximate a 27 feet/mile slope, and extend 10,650 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Street consist of 10.6 lane mile of asphalt, 59% of which is in good condition and 41% of which is in fair condition, and 6 lane miles of concrete, 54% of which is in good condition, and 46% of which is in fair condition.

E. Land Use

52.9 acres (41.5%) is 0.5 to 2 dwelling units per acre urban residential, of which 16.1 acres (30%) is impervious.

5.2 acres (4.1%) is > 8 dwelling units per acre urban residential, of which 3.1 acres (60%) is impervious.

8.4 acres (6.6%) is Linear Strip Development, of which 4.9 acres (58%) is impervious.

10.1 acres (7.9%) is Shopping Center, of which 10.1 acres (100%) is impervious.

49.2 acres (38.6%) is Urban Parkland or Open Space, of which 1.2 acres (2%) is impervious.

1.8 acres (1.4%) is Urban Institutional, of which 1.7 acres (94%) is impervious.

Approximately 29% imperviousness in entire catchment area.

IV. Catchment Name - MI 1,DRF, Bogus Swamp Drain

A. Area - 112.7 acres.

B. Population - 480 persons.

C. Drainage - This catchment area has a representative slope of 233 feet/mile, 42% served with curbs and gutters and 58% served with swales and ditches. The storm sewers approximate a 32 feet/mile slope, extending 9,980 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist 10.1 lane miles of asphalt, of which 62% is in good condition and 385 is in fair condition, and 5.8 lane miles of concrete, 54% of which is in good condition, and 46% of which is in fair condition.

E. Land Use

38.0 acres 33.7% is 0.5 to 2 dwelling units per acre urban residential, of which 13.4 acres (35%) is impervious.

5.2 acres (4.6%) is 8 dwelling units per acre urban residential, of which 3.1 acres (60%) is impervious.

8.4 acres (7.4%) is Linear Strip Development, of which 4.9 acres (58%) is impervious.

10.1 acres (9%) is Shopping Center, of which 10.1 acres (100%) is impervious.

49.2 acres (43.7%) is Urban Parkland or Open Space, of which 1.2 acres (2%) is impervious.

1.8 acres (1.6%) is Urban Institutional, of which 1.7 acres (94%) is impervious.

Approximately 31% imperviousness in the entire catchment area.

V. Catchment Name - MI 1,GCO, Bogus Swamp Drain

A. Area - 67 acres.

B. Population - 340 persons.

C. Drainage - This catchment area has a representative slope of 200 feet/mile, 48% sered with curbs and gutters, and 52% served with swales and ditches. The storm sewers approximate 29 feet/mile slope, extending 5,480 feet.

D. Sewerage - Drainage area of this catchment is 100% separate storm sewers.

Streets consist of 6.6 lane miles of asphalt, all in good condition, and 3.0 lane miles of concrete, 37% in good condition and 63% fair condition.

E. Land Use

15.0 acres (22.4%) is 0.5 to 2 dwelling units per acre urban residential, of which 7.3% acres (49%) is impervious.

5.2 acres (7.8%) is > 8 dwelling units per acre urban residential, of which 3.1 acres (60%) is impervious.

10.1 acres (15.1%) is Shopping Center, of which 10.1 acres (100%) is impervious.

36.7 acres (54.8%) is Urban Parkland or Open Space, of which 0.6 acres (2%) is impervious.

Approximately 31% imperviousness in the entire catchment area.

VI. Catchment Name - MI 1,GC1, Bogus Swamp Drain

A. Area - 30.3 acres.

B. Population - 340 persons.

C. Drainage - This catchment area has a representative slope of 121 feet/mile, completely served with curbs and gutters. The storm sewers approximate 22 feet/mile slope, extending 4800 feet.

D. Sewerage - Drainage area of this catchment is 100% separate storm sewers.

Streets consist of 6.1 lane miles of asphalt, all in good condition, and 3 lane miles of concrete, of which 37% in good condition and 63% is in fair condition.

E. Land Use

15.0 acres (47.5%) is 0.5 to 2 dwelling units per acre urban residential, of which 7.3 acres (49%) is impervious.

5.2 acres (17.2%) is > 8 dwelling units per acre urban residential, of which 3.1 acres (60%) is impervious.

10.1 acres (33.3%) is Shopping Center, of which 10.1 acres (100%) is impervious.

Approximately 68% imperviousness in the entire catchment area.

VII. Catchment Name - MI 1,UP1, Bogus Swamp Drain

A. Area - 163.9 acres.

B. Population - 850 persons.

C. Drainage - This catchment area has a representative slope of 226 feet/mile, with 21.0% curbs and gutters, and 79.0% having swales and ditches, the total extending 15,530 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 14 lane miles of asphalt which are all in fair condition, and 1.7 lane miles of concrete roadways, all in good condition.

E. Land Use

29.3 acres (17.9%) is 0.5 to 2 dwelling units per acre urban residential, of which 6.5 acres (22%) is impervious.

61.6 acres (37.6%) is 2.5 to 8 dwelling units per acre urban residential, of which 16.1 acres (26%) is impervious.

0.6 acres (0.4%) is Linear Strip Development, of which 0.6 acres (100%) is impervious.

16.4 acre (10%) is Urban Industrial (heavy) of which 12.3 acres (75%) is impervious.

33.2 acres (20.3%) in Urban Parkland or Open Space, of which 0.6 acres (2%) is impervious.

22.8 acres (13.9%) is Urban Institutional, of which 8.7 acres (38%) is impervious.

Approximately 26% imperviousness in the entire catchment area.

VIII. Catchment Name - MI 1,UP2, Bogus Swamp Drain

A. Area - 74.9 acres.

B. Population - 370 persons.

C. Drainage - This catchment area has a representative slope of 194 feet/mile, with 47% having curbs and gutters, and 53% having ditches and swales, the total extending 9,230 feet at a representative slope of 63 feet/mile.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 8.9 lane miles of asphalt, all in fair condition, and 1.7 lane miles of concrete, all in good condition.

E. Land Use

1.8 acres (2.4%) is 0.5 to 2 dwelling units acre urban residential, of which 1.3 acres (72%) is impervious.

33.9 acres (45.3%) is 2.5 to 8 dwelling units per acre urban residential, of which 5.5 acres (16%) is impervious.

16.4 acres (21.9%) is Urban Industrial (heavy) of which 12.3 acres (75%) is impervious.

22.8 acres (30.4%) is Urban Institutional, of which 8.7 acres (38%) is impervious.

Approximately 37% imperviousness in the entire catchment area.

PROBLEM

A. Local definition (government)

The present water quality of the Grand River is capable of supporting a fishery in pike, bass, catfish and bluegill. Contact recreation use is denied primarly due to the high levels of coliform in the river, which come from the combined sewer overflows in the area, although none are included in the catchment areas being evaluated in this project.

Water quality problems have been identified as also resulting from agricultural runoff, benthal demand, and urban runoff. The problems experienced include high nutrient levels and eutrophication and low dissolved oxygen. The principal water supply source is ground water, causing concern of possible contamination from urban runoff, or the feasibility of using stormwater for recharge, from the Red Cedar River, which is underlain by sand/gravel.

B. Local Perception (public awareness)

With the exception of boating and fishing, most residents travel to Lake Lansing, which is used as the principle local recreational water body in the area. They are aware of the current unsuitability of the Grand River for body contact recreation. As the linear parks along the river continue to be developed, increased interest in the utilization of the river for recreation may be expected.

PROJECT DESCRIPTION

A. Major objectives

Previous studies conducted in the Lansing, MI, area have resulted in the conclusion that water quality problems do exist in the Grand River which impair desired beneficial use. Further, urban nonpoint source pollution has been identified as a major contributor to biochemical oxygen demand, nitrogen, and suspended solids. This study is designed to determine the efficiency of three best management practices to enhance storm water quality from urban runoff. The three best management practices consist of an in-line wet storage basin, a dry detention basin, and two up-sized sections of underground storm drain pipe.

Specific study objectives include:

1. Determination of pollutant loads transported in the stormwater, as it enters and leaves each best management practice structure, and related land use;
2. Assessment of the impact these practices can have on the receiving water quality in the project area and regionally;
3. Identification of the financial requirements for capital and operating and maintenance costs for these types of controls, and;
4. Transfer of the information developed to other agencies in the region, for their use in implementation of pollution control plans.

B. Methodology

Atmospheric deposition sampling is providing information on the atmospheric input of pollutants under both wet and dry conditions. The quantity and quality of flow into and out of the best management practices control features are being determined during storm event conditions through appropriate measuring and analytical procedures. Sediments collected in the wet retention basin and the up-sized stormdrain sections are also scheduled for analysis.

The two up-sized pipe sections were installed with crown elevations at the same elevation as the smaller diameter inlet and outlet pipes. This resulted in standing water depth above the pipe inverts of 36 and 42 inches. This design will provide conditions favorable to sedimentation for storms which occur frequently during the year. To prevent flushing of deposited solids during high peak flows, periodic removal of the accumulated sediment will be evaluated with respect to timing and cost.

C. Monitoring

Field sampling of runoff water quality, flow and precipitation, initiated in April, 1980, at some of the monitoring stations, has gradually been extended to all the stations, as construction activites were completed, and other problems encountered were eliminated.

Monitoring locations are identified in Figure 2. Water quality and flow data for inlet and outlet flows and in the Grand River are being obtained from ENCOTEC, a consulting firm located in Ann Arbor, MI. In addition to the 11 locations identified, a monthly grab sample is obtained at each of the two stations (one located upstream and one located downstream of Lansing) sampled by the Michigan Department of Natural Resources. These particular samples are needed for analysis of those parameters not being evaluated by the state which are of interest in this program. Two sampling locations have been established for bulk fallout, and dryfall/wetfall sampling, with respect to evaluating the atmospheric pollutant contribution.

The list of parameters and constituents examined in the sample collected includes: total solids, total suspended solids, pH, total alkalinity, specific conductance, choride, turbidity, total organic carbon, ammonia nitrogen, nitrate plus nitrite nitrogen, soluble and total Kjeldahl nitrogen, soluble and total organic carbon, soluble total phosphorus, orthophosphate, grease and oil, biochemical oxygen demand, chemical oxygen demand, total metals-to include lead, iron, zinc, chromium, copper, nickel, cadmium, mercury and arsenic, PCB, total fluoride, orthophosphate, phenolics, sulfide, a pesticide scan, and particle distribution.

Equipment

The sites will be monitored using automatic flow recording devices of a type suitable for specific installation, and automatic discrete/composite water samplers, except for grab sample points in the Grand River. Wetfall and dryfall sampling is also done using automatic sampling equipment. Sediments removed from the best management practice control structures will be subjected to particle size analysis.

Control

The four best management practices structures will be evaluated to determine their effectiveness as control measures to reduce the pollutant effect of urban stormwater runoff.

NATIONWIDE URBAN RUNOFF PROGRAM

SOUTHEAST MICHIGAN COUNCIL OF GOVERNMENTS
OAKLAND COUNTY, MICHIGAN

DETROIT, MI

REGION V, EPA

INTRODUCTION

The Southeast Michigan Council of Governments project is centered in the City of Troy, in Southeast Michigan, about 15 miles northwest of Detroit. Topography in the area is very flat, with poor drainage. Drains carry runoff to the Clinton River and then to Lake St. Clair.

The Clinton River, not specifically assigned a classification by name, must, as a minimum, be protected for agricultural uses, navigation, industrial water supply, public water supply at the point of intake, warmwater fish, and partial body contact recreation. As one of the site selection criteria, the sub-drainage area identified as the Red Run sub-basin, which exhibited poor known stormwater-induced quality, was chosen.

Other siting criteria used in selecting Troy were, the requirement for an area of poor drainage, yet highly urbanized and within close proximity to a concentration of raingages. The extreme southeast corner of Oakland County is very flat, and has experienced rapid urbanization, both factors exacerbating the problem that flat terrain causes for stormwater runoff. This area has also become highly urbanized during the past 20 years, and Southeast Michigan Council of Governments has a raingage network in the area. Troy's population has increased approximately 350% since 1960.

As municipal and industrial wastewater treatment has reduced the degree or level of pollution attributable to point source pollution, an increasing awareness has developed regarding the significant contribution from nonpoint sources, especially in southeast Michigan. SEMCOG studies have identified urban stormwater runoff as an important factor in water quality degradation.

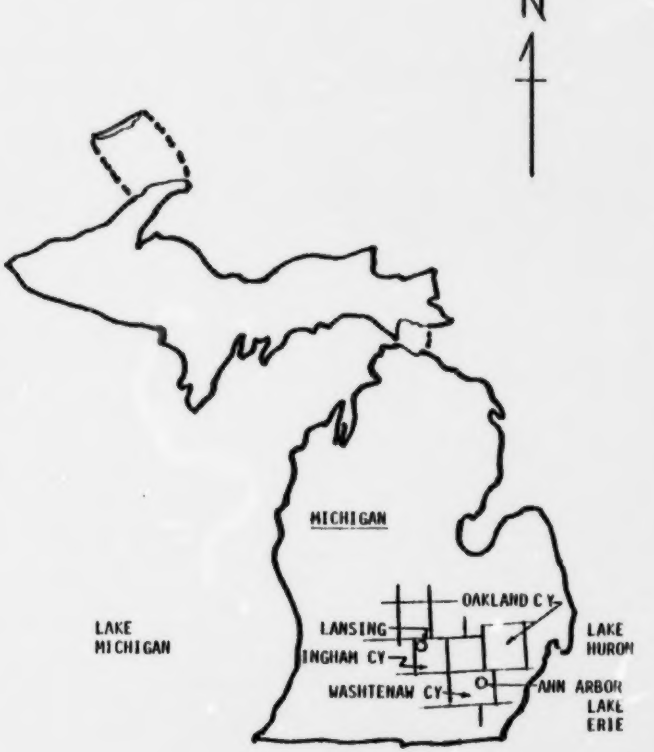


FIGURE 1

PHYSICAL DESCRIPTION

A. Area

The City of Troy, located in Oakland County, is about 15 miles to the northwest of Detroit, or about 5 miles southeast of Pontiac, Michigan. The total area of the city comprises about 31 square miles. Land use within the city is best characterized as residential and commercial development.

B. Population

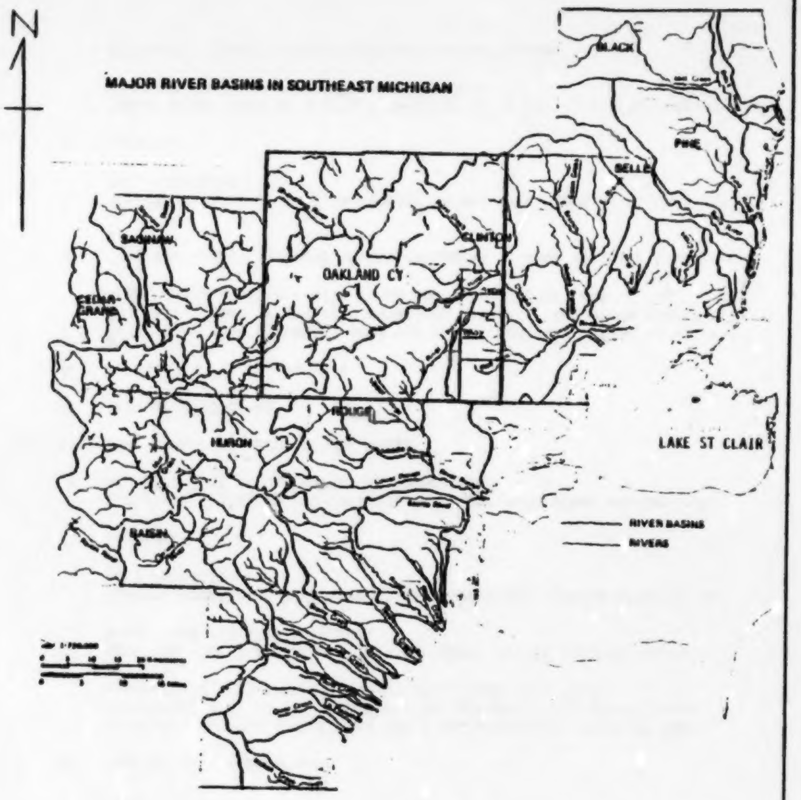
Troy has experienced very large increases in population over the last twenty years from about 19,100 in 1960 to about 67,100 in 1980. During this same period, Oakland County has increased from about 668,800 to 1,011,793, a 51.3 percent increase. The rate of increase in population for Troy was 106.8% from 1960 to 1970, and 70.2% from 1970 to 1980. Although the rate of increase has slowed, it is reasonable to expect that the population will continue to grow in the future. The year 2,000 projected population is 70,800.

C. Drainage

The southeastern area of Michigan, including the City of Troy, is very flat. As a result it is poorly drained. Drainage is accomplished through storm drains which connect to the Clinton River and its tributaries, which flows into Lake St. Clair. Developments are required to include detention basins to slow storm runoff and prevent downstream flooding.

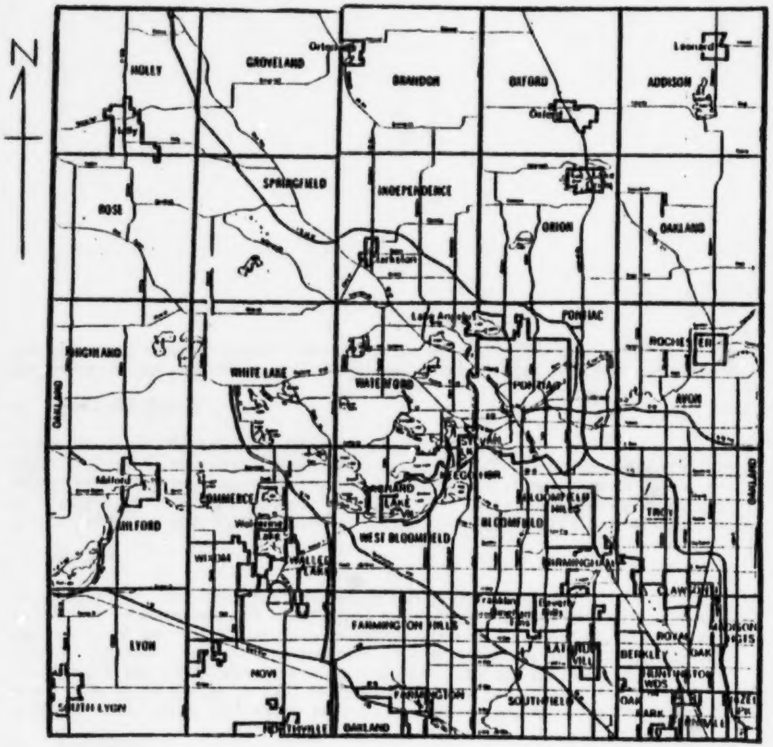
D. Sewerage System

The existing sewerage system is completely separate, with suitable treatment of the collected sanitary sewage, and discharge of the effluent.



CLINTON RIVER BASIN

FIGURE 2



OAKLAND COUNTY COMMUNITIES

FIGURE 3

PROJECT AREA

I. Catchment Name - MI 2, Catchment 100, VILLAGE GREEN

- A. Area - 55.1 acres.
- B. Population - 275 persons.
- C. Drainge - This catchment area has a representative slope of 53.0 feet/mile, 3.8% served with curbs and gutters. The storm sewers approximate a 25 feet/mile slope and extend 2675 feet.
- D. Sewerage - Drainage area of the catchment is 75% separate storm sewers and 28% with no sewers.

  Streets consist of 1.05 lane-miles of asphalt, 100% of which is in good condition.
- E. Land Use

  2.8 acres (5.1%) is > 8 dwelling units per acre urban residential, of which 1.8% acres (64.3%) is impervious.

II. Catchment Name - MI, 200, BEAVER TRAIL

- A. Area - 127.3 acres.
- B. Population - 1,053 persons.
- C. Drainage - This catchment area has a representative slope of 53 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 13 feet/mile slope and extend 3,300 feet.
- D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

  Streets consist of 7.74 lane-miles of concrete, 100% of which is in good condition.
- E. Land Use

  106.9 acres (84%) is 2.5 to 8 dwelling units per acre urban residential, of which 12.3 acres (9.7%) is impervious.

  20.4 acres (16%) is Urban Parkland or Open Space.

III. Catchment Name - MI 2, 300, SYLVAN GLEN

A. Area - 97 acres.

B. Population - 459 persons.

C. Drainage - This catchment area has a representative slope of 53 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 29% feet/mile slope and extend 3,910 feet.

D. Sewerage - Drainage area of the catchment is 81.2% separate storm sewers.

Streets consist of 4.96 lane-miles of concrete, 100% of which is in good condition.

E. Land Use

78.8 acres (81.2%) is 0.5 to 2 dwelling units per acre urban residential, of which 9.5 acres (12%) is impervious.

18.2 acres (18.8%) is Urban Parkland or Open Space.

IV. Catchment Name - MI 2, 400, CITY OF TROY, RECORDING RAINGAGE

A. Area - 279.4 acres.

B. Population - 1,787 persons.

C. Drainage - This catchment area has a representative slope of 53 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 22.3 feet/mile slope and extend 9,885 feet.

D. Sewerage - Drainage area of the catchment is 79% separate storm sewers.

Streets consist of 1.05 lane-miles of asphalt, 100% of which is in good condition. In addition there are about 12.6 lane-miles of concrete, of which 100% is in good condition.

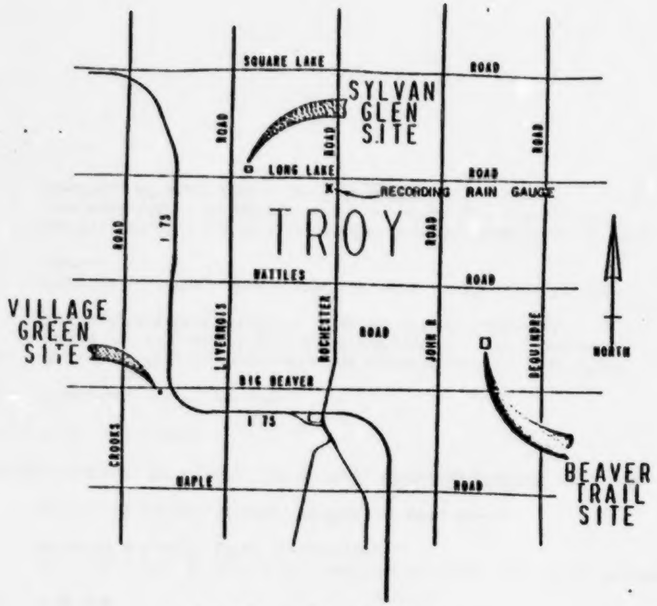
PROBLEM

A. Local Definition (Government)

SEMCOG identified stormwater generated pollution as a problem within their area of jurisdiction during the initial Section 208 planning work. Earlier, stormwater quantity problems had resulted in requirements for runoff control in subdivision developments to prevent downstream damage. In the rapidly urbanizing areas in southeastern Michigan, the topography is relatively flat, and poorly drained. Many stormwater detention basins have been constructed in compliance with quantity control requirements. Such basins might be suitably adapted through minor modifications to incorporate water quality control. This would eliminate potential water quality standards violations to the Clinton River drainage network, and denial of beneficial uses, if it proved cost-effective.

B. Local Perception (Public Awareness)

Public participation during the initial planning effort which identified urban stormwater runoff as a source of pollutants alerted the public to the problem. Continued communications with local elected officials and citizen leaders during the conduct of the NURP study has been a requirement, and scheduled task in the work plan. In addition, there is a public education program task included in the detailed plan, designed to educate the public before management recommendations are formulated.



TROY, MICHIGAN

GENERAL LOCATION MAP

FIGURE 4

PROJECT DESCRIPTION

A. Major Objective

The Oakland County project, as a continuation and follow-up Section 208 study, has been designed to evaluate the effectiveness of modified stormwater quantity control structures for use in event runoff quality control. In addition to this technical evaluation, the costs involved for the modifications, and subsequent maintenance costs and responsibilities will be reported. Legal and institutional aspects of an implementation program will be reviewed and recommendations presented concerning needs in these areas.

The project will extend over three years, with initial sampling and monitoring designed to determine the level of pollution existing in the selected drainage areas. Subsequent sampling will demonstrate the effectiveness of detention basin modifications in controlling the identified pollutants.

B. Methodology

The hypothesis being tested is that stormwater pollution control in newly developing areas can be achieved with relatively inexpensive modifications over present practices, specifically retention systems, used in control of stormwater quantity.

Consultant testing and evaluation require sampling of rainfall and urban runoff quantity and quality and engineering analysis of data. The engineering analysis is being performed to determine mass emissions of pollutants and the degree to which various retention structures and modifications to these structures reduce pollutant discharges. General pollutants of concern are suspended solids, oxygen demanding materials, toxics, and plant nutrients.

Studies concerning operation and maintenance requirements, both institutional and legal constraints and alternatives for implementation, and evaluation of overall costs and benefits are being conducted by SEMCOG, running concurrently with the sampling/engineering effort. Thus, the feasibility of using retention structures as a best management practice (BMP) for controlling stormwater runoff pollution in urban areas will be based on technical, legal, institutional, and economic considerations.

Information generated will be used by SEMCOG in conjunction with relevant work products from SEMCOG's 208 water quality management planning efforts to determine the relative costs and benefits and the institutional constraints involved in modifying existing stormwater quantity control systems for incorporation of permanent in-place stormwater quality control. In particular, design criteria and guidelines will be prepared by the consultant for use by local and nationwide site planners, engineers, and review agencies to incorporate and implement preventive control measures for urban nonpoint pollution. Results will also aid SEMCOG in the development of future basin-wide alternatives for controlling total urban pollutant loadings to the region's rivers.

The proposed effort in Southeast Michigan has been organized in conjunction with the Oakland County Drain Commissioner in order to incorporate the experience gained by the Commissioner through his successful administration of programs to enforce the Soil Erosion and Sedimentation Act (PA 347) and the Plat Act (PA 288), both of which often require stormwater retention basins. The Drain Commissioner's function is especially important to the long-term development of sound and comprehensive water resources management since it is the policy of SEMCOG to integrate a system of controls for urban nonpoint pollution into the present framework of laws and practices, wherever possible.

The retention control measures to be assessed in this project are those required under Michigan PA 288 of 1967. These controls are required in order to reduce excess runoff from development sites which are tributary to county drains with little additional hydraulic capacity. Retention structures are designed to protect against the ten-year storm event. Should these structures provide significant improvement in water quality, it may be possible to implement a comprehensive storm drainage program which provides both flood protection and water quality benefits.

Many variables affect the treatment efficiency of retention basins. For instance, three major variables affect the efficiency of a basin for settling out particulates; these are: (1) influent particle size distribution, (2) magnitudes and timing of water flow, and (3) basin configuration. In turn, these first two variables are a function of rainstorm intensity, antecedent dry periods, drainage area land cover/use characteristics (e.g., soil types, percent impermeable area, seasonal activities, slope), and the design and efficiency of the stormwater conveyance system.

Previous SEMCOG studies have focused on the problem of characterizing runoff pollutant loads from different land uses. From these efforts, it has been concluded that pollutant load characteristics of runoff from commercial and residential areas differ significantly. Hence, the kinds of control measures necessary to abate stormwater-associated water pollution may vary according to the land use in the storm drainage district. Accordingly, this project considers two categories of land use: residential and commercial.

Seventeen runoff events are projected to be sampled over the course of the project. Ideally, two of these events will be snowmelts with one sampled early each Spring. The remaining events will be rainfall events.

C. Monitoring

Three test sites have been selected for the purposes of this project. Two of the sites are residential and one is commercial. All are less than 135 acres, have curbs and gutters, and exemplify typical development in many areas of the nation. Their descriptions follow:

The Beaver Trail Sub. No. 2 and 3 retention basin is located off Pasadena near Traverse. The basin is in good condition with some weed growth at the northerly end due to wet conditions at the two 54-inch inlets. Existing manholes on the 54-inch inlets can be utilized as monitoring manholes for inflow.

The Beaver Trail retention basin has a capacity of 1,292,000 ft^3 (cubic feet). Based on current design requirements of the Oakland County Drain Commission, required capacity of the retention basin is 405,628 ft^3. The design area is 135 acres with a runoff "c" factor 0.42. The time from start of rainfall to peak storage is approximately 118 minutes for the design storm. The time of concentration for the drainage area is approximately 31 minutes. The base rainfall of 0.5 inches would generate approximately 103,000 ft^3 of runoff to the retention basin. This volume would cause a depth of water at the 16 inch outlet of approximately 2.7 feet, assuming no outflow. The contributing area of this retention basin is entirely residential with the exception of some open space immediately east of the retention basin.

The Sylvan Glen Sub. No. 2 retention basin is located adjacent to the northeast corner of Long Lake Road and Berwyck. This basin is in excellent condition, well maintained with no excessive weed or cat-tail growth. There is no outlet structure visible which could serve as a monitoring manhole. The Sylvan Glen retention basin has a capacity of 220,000 ft^3. The design area is 75 acres with a runoff "c" factor of 0.42. The time from start of rainfall to peak storage is approximately 100 minutes. The time of concentration for the drainage area is approximately 37 minutes.

The base rainfall of 0.5 inches would generate approximately 40,837 ft^3 of runoff to the retention basin. This volume would cause a depth of water of 4 feet at the 12-inch outlet, assuming no outflow.

The contributing area to this retention basin is entirely residential.

The Village Green of Troy retention basin is located southwest of the Big Beaver Road (16 Mile Road)/I-75 interchange. This basin is in generally excellent condition with short grasses over a majority of the site. Some erosion and standing water is present near the inlet. Manholes exist on the inlet off-site and on the outlet on-site. These existing structures show promise for use as sampling stations.

The Village Green of Troy retention basin has a capacity of 1,466,000 ft^3. Based on current design requirements of the Oakland County Drain Commission, required capacity of the retention basin is 776,480 ft^3. The design area is 60 acres with a runoff "c" factor of 0.6. The time from start of rainfall to peak storage is 148 minutes for a design storm. The time of concentration of the drainage area is approximately 26 minutes.

The base rainfall of 0.5 inches would generate approximately 65,300 ft^3 of runoff to the retention basin. This would cause a depth of water at the 10-inch outlet of approximately 4 feet, assuming no outflow.

The contributing area to this retention basin is multiple dwellings and commercial use. The high ratio of land used for parking and building increases the imperviousness of the area, resulting in runoff factors higher than those for the residential areas.

Stormwater runoff from the three basin catchments for 17 events planned to be collected at the inlet and outlet of each of the three stormwater retention basins will be analyzed and evaluated.

The three basins described have been selected for study. Two have one inlet and one outlet, and one has two inlets and one outlet for a total of seven stations. The flow recording instrument is a continuous flow recorder. One will be installed at each inlet and outlet. This instrument is required in order to overcome the prevailing site conditions which would cause errors in flow measurement if other methods were employed. The units will provide accurate flow measurements even though surcharge conditions do or can exist at each station; low flows will lead to open channel flow, and peak flows will result in fullpipe flows. Influent and effluent hydrographs will be produced for each event.

Automatic water sampling equipment will be coupled to and be paced by the flow recorders. Regardless of the flow regime at any point in the storm event, this combination of equipment will produce a representative flow weighted composite sample for analysis at the basin inlets and outlets.

At least two members of the sampling team will be on call during periods when the designated weather service indicates a reasonable probability of an appropriate storm event occurring. The data gathering team will mobilize to the retention basins immediately upon the onset of the precipitation event. Precipitation and flow measurements will then be performed on a time related basis to enable correlation with rain gauge data from the SEMCOG network and gauges added at the retention basin site.

Loadings at each influent and effluent for each event will be determined/estimated for each parameter in the following list:

- Biochemical Oxygen Demand (BOD)
- Total Organic Carbon (TOC)
- Chemical Oxygen Demand (COD)
- Total Phosphorus
- Orthophosphate
- Total Kjeldahl Nitrogen (TKN)
- Ammonia Nitrogen
- Nitrate and Nitrite Nitrogen
- Metal Ions (Pb, Fe, Zn, Cr, Cd, Cu, Ni, As, Hg)
- Pesticides (8, chlorinated)
- Total Suspended Solids (TSS)
- Total Dissolved Solids (TDS)
- Particle Size Analysis (1u, 4u, 10u, 62.5u, 125u)
- Fecal Coliform
- ph
- Chloride

Precipitation data is also needed with respect to events. Quantity - A rain event history including the rain duration, intensity and quantity will be determined for each event and basin which is monitored. The primary source of rainfall quantity information will be the recording rain gauge located near the junction of Long Lake River and Rochester Roads in Troy. This gauge

is within approximately two miles of the retention basins which have been selected for study and is part of SEMCOG's raingauge network. Hyetographs will be constructed from this data to assist in characterization of the storm event. In addition, manually read rain gauges will be placed adjacent to each test basin to verify the uniformity of precipitation or to allow for adjustments in the rainfall volumes for a given basin should the precipitation event prove to be non-uniform.

Quality - The chemical characteristics of the rainfall will also be sampled as a part of this program. It is presently projected to perform such sampling at one of the three test basins during each storm event monitored. This task will require locating a relatively large rainfall collector pan in the immediate vincinity of one of the test basins. This approach will provide information not only as to the potential for pollutants to be contributed by atmospheric washout in general, but also to the determination of whether any localized situation alters the rainfall chemical characteristics between the basins being studied.

At least initially, the parameters to be evaluated on the collected precipitation samples will include the majority of those to be investigated with respect to the retention basins.

Precipitation Parameters

- Biochemical Oxygen Demand (BOD)
- Total Organic Carbon (TOC)
- Total Phosphorus
- Total Kjeldahl Nitrogen
- Ammonia Nitrogen
- Nitrate plus Nitrite Nitrogen
- Metal Ions (Pb, Fe, Zn, Cr, Cd, Cu, Ni, As, Hg)
- pH
- Chloride

D. Controls

As previously described, this project is evaluating existing stormwater detention basins installed for quantity control, and modified for quality control, for effectiveness and costs.

NATIONWIDE URBAN RUNOFF PROGRAM

SOUTHEAST MICHIGAN COUNCIL OF GOVERNMENTS
ANN ARBOR - MICHIGAN

DETROIT, MICHIGAN

U.S. ENVIRONMENTAL PROTECTION

REGION V

INTRODUCTION

The City of Ann Arbor, situated in Washtenaw County is located in southeastern Michigan, approximately 60 miles west of Detroit. Ann Arbor's surface topography was determined largely by glacial processes. Rolling hills predominate with some interspersed flat areas, pothole lakes, and wetlands. Occasional steep slopes will be found. The area includes an extensive system of storm-drains consisting of both open and enclosed channels. Main lines tend to follow the course of former natural streams, and outlet to the Huron River which passes through Ann Arbor in a series of run-of-the-river impoundments. The Huron river flows directly into the western basin of Lake Erie.

The impoundment above Geddes Dam in Ann Arbor, which reaches about one-half the distance upstream to Argo Dam, is identified as Geddes Pond. This water body is identified in the Michigan State Water Quality Standards as protected for partial body contact recreational use with a goal for total body contact recreational use in the future. The free-flowing stretch of the Huron River would come under the general classification of being protected for agricultural uses, navigation, industrial water supply, public water supply at the point of water intake, warmwater fish, and partial body contact recreation. There have been water quality standards violations.

Water quality surveys conducted in the 1970's generally disclosed water quality conditions during dry weather flow to be reasonably good, while pollutant levels increased dramatically during stormwater runoff periods. The population in the area has shown considerable growth, increasing from about 67,000 in 1960 to about 107,000 in 1980, a rate of 60% in 20 years. The rate has slowed down during ten years from 1970 to 1980, with a gain of only about 7.5%. This still would result in a projection of further growth during the next twenty years. Population may easily reach 115,000 with continued urbanization, since the growth rate in the urbanized area was 16.7% between 1970 and 1980.

The Southeast Michigan Council of Governments, in the development of the Section 208 Management Plan, identified the reach of the Huron River between the Argo and Geddes Dams as one of three problem areas. With no point source discharges, the focus is on nonpoint sources in this stretch of the river. The SEMCOG Section 208 program included an overall approach for managing pollution from urban nonpoint sources of pollution. The area in which this project is located had the highest priority of the three identified problem areas.

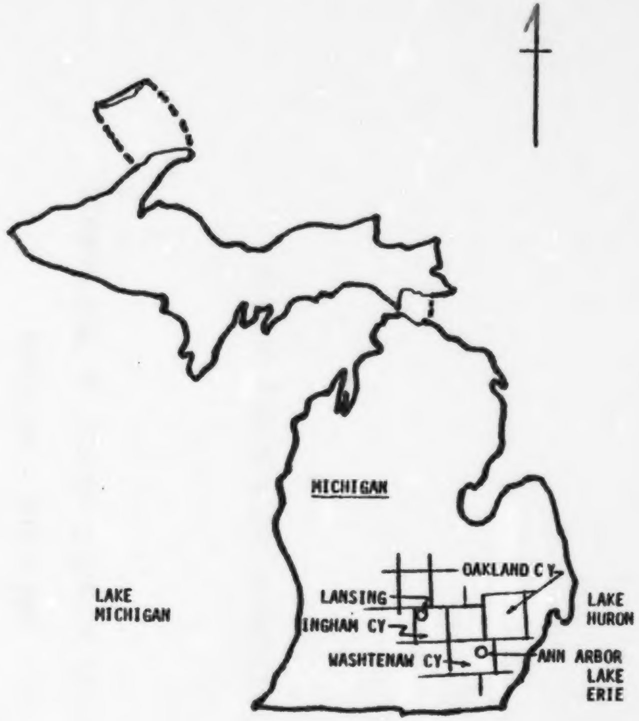
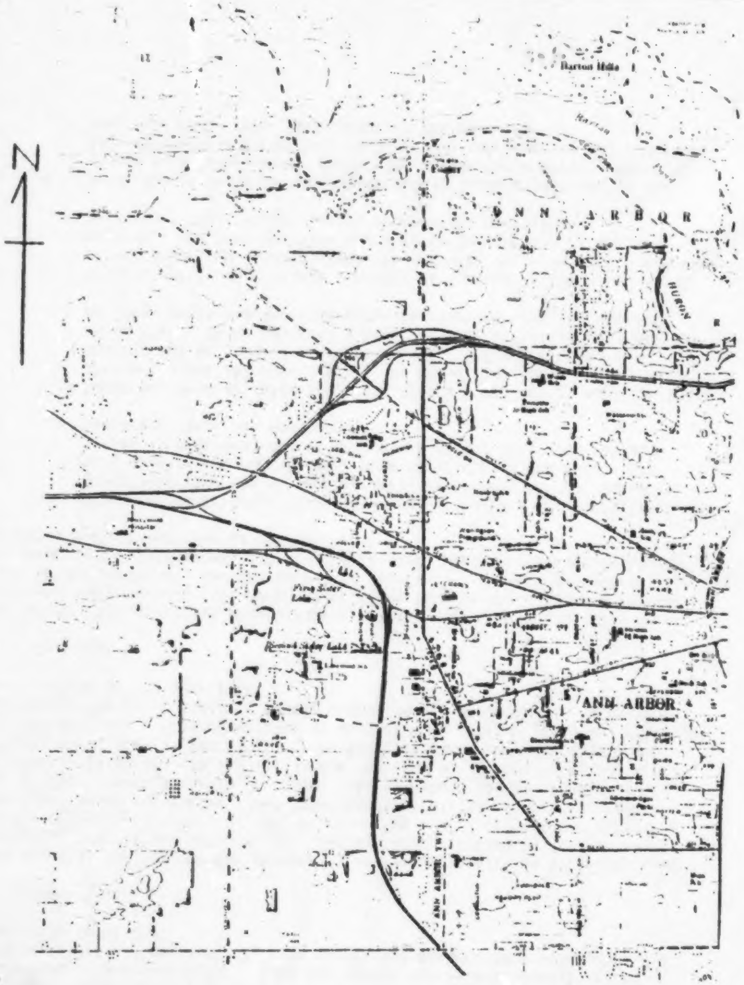


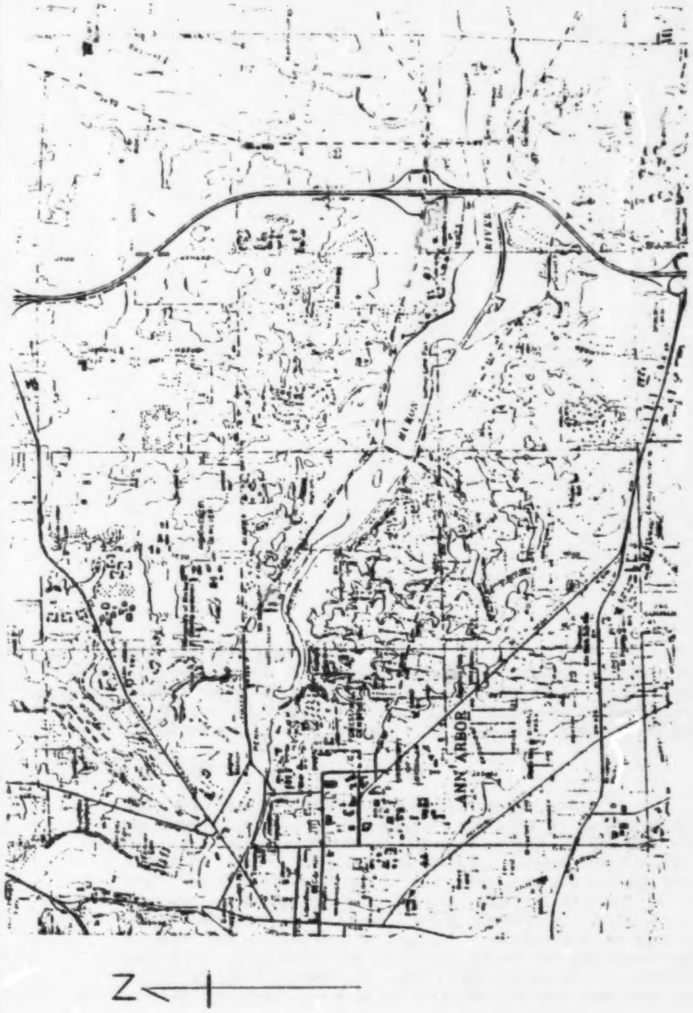
FIGURE 1



ANN ARBOR STREETS
USGS QUAD SHEET

FIGURE 2A

Reproduced from
best available copy.



ANN ARBOP STREETS, USGS QUAD SHEET

FIGURE 2B

PHYSICAL DESCRIPTION

A. Area

The City of Ann Arbor, situated in Washtenaw County, is located in southeastern Michigan, approximately 60 miles west of Detroit. The total area of the city comprises 26.5 square miles. Land use within the town is characterized as institutional and residential, with associated commercial development, and some industrial use.

B. Population

Ann Arbor is the home of the University of Michigan, with parts of the campus on either side of the Huron River. The census population figure for the City of Ann Arbor for 1970 was 99,797, representing a 48.2 precent increase from the 1960 census population. The 1980 Census population figure was reported as 107,316, a much lower 7% increase. The Washtenaw County standard metropolitan statistical area population was reported as increasing by 35.8% from 1960 to 1970, when it was 234,103. By 1980, it had become 264,103, a 14 percent increase. City population is projected to continue to grow, although not as rapidly as in the last twenty years, and is projected to increase to about 115,00 by the year 2000.

C. Drainage

Ann Arbor's topography is predominately rolling hills, with some flat areas, potholes and wetlands. The Huron River flows through the city from the northwest to the southeast, through both free flowing and impounded reaches. The drainage in sub-watersheds is divided into five specific drainage districts (Figures 3-6), identified as follows:

a. Traver Creek Drainage District, rural and with a relatively flat grade away from the urbanizing area, it becomes steeper and with more development downstream. Much flood damage has been experienced in this area due to the nature of the watershed shape, streambed slope and development.

b. Swift Run Drainage District, also agricultural in the upper portion, includes a wetland preserved by the Drain Commission to provide storage and water quality improvements. Below the wetland, to the Huron River, there has been a high level of urbanization, reducing pervious areas and increasing runoff rates through stormdrains.

c. Allen Creek Drain Drainage District is located in the urban areas of Ann Arbor and is extensively served with an enclosed storm drainage network. The configuration and intense development result in a very short time requirement to concentrate peak flows.

d. North Campus Drain Drainage District is located adjacent to the Traver Creek Drain onthe north side of the Huron River. There is less development along this open natural watercourse, which outlets into the Geddes Pond impoundment of the Huron River.

e. The Pittsfield-Ann Arbor Drain Drainage District comprised the sub-watershed lying between the Allen Creek and Swift Run Drain Drainage Districts. This drain has been modified by straightening, deeping, widening and enclosing some portions. In addition, on-line retention basins have been constructed. The Pittsfield-Ann Arbor Drain Drainage District can be divided into 3 sub-districts. The South arm district comprises approximately 31% of the total area and has the least impervious area. The North arm district includes part of the University with attendant high density residences and some commercial development. The remaining sub-district is highly urbanized and contains the most impervious surface area.

D. Sewerage System

The sanitary wastes are carried through a separate collection system to treatment facilities, with the treated effluent discharged to the Huron River below Geddes Dam. Although a separate sanitary sewer system was developed, in the Allen Creek Drain prior studies suggest that crossconnections exist within certain sub-districts.

The following station codes and descriptors identify the locations of the monitoring stations:

Descriptor	Station Code
Pittsfield-Ann Arbor Drain	
South Inlet	PITAARETBNSINLT
North Inlet	PITAARETBNNINLT
Basin Outlet	PITAA RET BN OT
Outlet to River	PITTS-AA DR OT
Swift Run Drain	
Inlet	SR WETLANDS INT
Outlet	SR WETLANDS OT
Outlet to River	SWIFT RUN DR OT
Traver Creek Drain	
Outlet to River	TRAV CK DR OT
Basin Inlet	TRAV CK RT BN I
Basin Outlet	TRAV CK RT BN O
North Campus Drain	
Outlet to River	N CAMPUS DR OT
Allen Drain	
Outlet to River	ALLEN DR OUTLET

450

PROJECT AREA

I. Catchment Name - MI3, PITAARETBNSINLT

A. Area - 2001 acres.

B. Population - 3800 persons.

C. Drainage - This catchment area has a representative slope of 33.8 feet/mile, 30% served with curbs and gutters and 70% served with swales and ditches. The storm sewers approximate a 17.6 feet/mile slope and extend 10,000 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 35 lane miles of asphalt, 54% of which is in good condition and 46% of which is in fair condition. In addition there are about 15 lane miles of concrete, all of which is in good condition, and 2 lane miles of other materials, all of which is in good condition.

E. Land Use

345 acres (17.2%) is < 0.5 dwelling units per acre urban residential, of which 4 acres (1.2%) is impervious.

117 acres (5.8%) is 0.5 to 2 dwelling units per acre urban residential, of which 5 acres (4.3%) is impervious.

62 acres (3.1%) is 2.5 to 8 dwelling units per acre urban residential, of which 30 acres (48.4%) is impervious.

92 acres (4.6%) is > 8 dwelling units per acre urban residential, of which 64 acres (69.6%) is impervious.

457 acres (22.8%) is Commercial, of which 264 acres (57.8%) is impervious.

138 acres (6.9%) is Industrial, of which 12 acres (8.7%) is impervious.

485 acres (24.2%) is Parkland, of which 42 acres (8.7%) is impervious.

305 acres (15.2%) is Agriculture, of which 4 acres (1.3%) is impervious.

II. Catchment Name - MI3, PITAARETBNNINLT

A. Area - 2871 acres.

B. Population - 18,800 persons.

C. Drainage - This catchment area has a representative slope of 60.7 feet/mile, 68% served with curbs and gutters and 32% served with swales and ditches. The storm sewers approximate a 10.6 feet/mile slope and extend 10,200 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 89 lane miles of asphalt, 58% of which is in good condition, 40% of which is in fair condition, and 2% of which is in poor condition. In addition there are about 9 lane miles of concrete, all in good condition, and 4 lane miles of other materials, all of which is in good condition.

E. Land Use

11 acres (0.4%) is < 0.5 dwelling units per acre urban residential, of which 1 acre (9.1%) is impervious.

241 acres (8.4%) is 0.5 to 2 dwelling units per acre urban residential, of which 17 acres (7%) is impervious.

938 acres (32.7%) is 2.5 to 8 dwelling units per acre urban residential, of which 293 acres (31.2%) is impervious.

378 acres (13.2%) is > 8 dwelling units per acre urban residential, of which 220 acres (58.2%) is impervious.

293 acres (10.2%) is Commercial, of which
150 acres (51.2%) is impervious.

80 acres (2.8%) is Industrial, of which
40 acres (50%) is impervious.

618 acres (21.5%) is Parkland, of which
26 acres (4.2%) is impervious.

312 acres (10.9%) is Agriculture, of which
6 acres (1.9%) is impervious.

III. Catchment Name - MI3, PITAA RET BN OT

A. Area - 4872 acres.

B. Population - 22,600 persons.

C. Drainage - This catchment area has a representative slope of 45.5 feet/mile, 52% served with curbs and gutters and 48% served with swales and ditches. The storm sewers approximate a 14.1 feet/mile slope and extend 20,000 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 124 lane miles of asphalt, 57% of which is in good condition, 41% of which is in fair condition, and 2% of which is in poor condition. In addition there are about 6 lane miles of concrete, all in good condition, and 6 lane miles of other materials, all of which is good condition.

E. Land Use

356 acres (7.3%) is < 0.5 dwelling units per acre urban residential, of which 5 acres (1.4%) is impervious.

358 acres (7.4%) is 2.5 to 8 dwelling units per acre urban residential, of which 22 acres (6.2%) is impervious.

1000 acres (20.5%) is 2.5 to 8 dwelling units per acre urban residential, of which 323 acres (32.3%) is impervious.

470 acres (9.6%) is > 8 dwelling units per acre urban residential, of which 284 acres (60.4%) is impervious.

750 acres (15.4%) is Commercial, of which
414 acres (55.2%) is impervious.

218 acres (4.5%) is Industrial, of which
52 acres (23.8%) is impervious.

1103 acres (22.6%) is Parkland, of which
68 acres (6.2%) is impervious.

617 acres (12.7%) is Agriculture, of which
10 acres (1.6%) is impervious.

IV. Catchment Name - MI3, PITTS-AA DR OT

A. Area - 6,363 acres.

B. Population - 27,700 persons.

C. Drainage - This catchment area has a representative slope of 61.6 feet/mile, 75% served with curbs and gutters and 25% served with swales and ditches. The storm sewers approximate a 15.4 feet/mile slope and extend 33,900 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 209 lane miles of asphalt, 49% is in good condition, 50% of which is in fair condition, and 1% of which is in poor condition. In addition, there are about 26 lane miles of concrete, all in good condition, and 8 lane miles of other materials, all in good condition.

E. Land Use

356 acres (5.6%) is < 0.5 dwelling units per acre urban residential, of which 5 acres (1.4%) is impervious.

483 acres (7.6%) is 0.5 to 2 dwelling units per acre urban residential, of which 29 acres (6%) is impervious.

1714 acres (26.9%) is 2.5 to 8 dwelling units per acre urban residential, of which 462 acres (27%) is impervious.

510 acres (8%) is > 8 dwelling units per acre urban residential, of which 314 acres (61.6%) is impervious.

861 acres (13.5%) is Commercial, of which 499 acres (58%) is impervious.

218 acres (3.4%) is Industrial, of which 52 acres (23.8%) is impervious.

1604 acres (25.2%) is Parkland, of which 88 acres (5.5%) is impervious.

617 acres (9.7%) is Agriculture, of which 10 acres (1.6%) is impervious.

V. Catchment Name - MI3, SR WETLANDS INT

A. Area - 1207 acres.

B. Population - 2700 persons.

C. Drainage - This catchment area has a representative slope of 32.1 feet/mile, 13% served with curbs and gutters and 87% served with swales and ditches. The storm sewers approximate a 6.9 feet/mile slope and extend 8,000 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 5 lane miles of asphalt, 20% of which is in good condition and 80% of which is in fair condition. In addition there area about 3 lane miles of concrete, all in good condition, and 5 lane miles of other materials, all in good condition.

E. Land Use

509 acres (42.2%) is < 0.5 dwelling units per acre urban residential, of which 5 acres (1%) is impervious.

30 acres (2.5%) is 0.5 to 2 dwelling units per acre urban residential, of which 3 acres (10%) is impervious.

13 acres (1.1%) is 2.5 to 8 dwelling units per acre urban residential, of which 3 acres (23.1%) is impervious.

90 acres (7.5%) is > 8 dwelling units per acre urban residential, of which 23 acres (25.6%) is impervious.

4 acres (0.3%) is Commercial, of which 1 acre (25%) is impervious.

14 acres (1.2%) is Industrial, of which 3 acres (21.4%) is impervious.

187 acres (15.5%) is Parkland, of which 2 acres (1.1%) is impervious.

360 acres (29.8%) is Agriculture, of which 3 acres (0.8%) is impervious.

VI. Catchment Name - MI3, SR WETLANDS OT

A. Area - 1227 acres.

B. Population - 2,700 persons.

C. Drainage - This catchment area has a representative slope of 32.1 feet/mile, 13% served with curbs and gutters and 87% served with swales and ditches. The storm sewers approximate a 6.9 feet/mile slope and extend 8,000 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 5 lane miles of asphalt, 20% of which is in good condition and 80% of which is in fair condition. In addition there are about 3 lane miles of concrete, all in good condition, and 5 lane miles of other material, all in good condition.

E. Land Use

509 acres (41.5%) is < 0.5 dwelling units per acre urban residential, of which 5 acres (1%) is impervious.

30 acres (2.4%) is 0.5 to 2 dwelling units per acre urban residential, of which 3 acres (10%) is impervious.

13 acres (1.1%) is 2.5 to 8 dwelling units per acre urban residential, of which 3 acres (23.1%) is impervious.

90 acres (7.3%) is > 8 dwelling units per acre urban residential, of which 23 acres (25.6%) is impervious.

4 acres (0.3%) is Commercial, of which 1 acre (25%) is impervious.

14 acres (1.1%) is Industrial, of which
3 acres (21.4%) is impervious.

187 acres (15.2%) is Parkland, of which
2 acres (1.1%) is impervious.

360 acres (29.3%) is Agriculture, of which
3 acres (0.8%) is impervious.

20 acres (1.6%) is Wetlands.

VII. Catchment Name - MI3, SWIFT RUN DR OT

A. Area - 3075 acres.

B. Population - 10,800 persons.

C. Drainage - This catchment area has a representative slope of 39.6 feet/mile, 42% served with curbs and gutters and 58% served with swales and ditches. The storm sewers approximate 17.8 feet/mile slope and extend 24,000 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 63 lane miles of asphalt, 38% of which is in good condition and 62% of which is in fair condition. In addition there are about 15 lane miles of concrete, all of which is in good condition, and 9 lane miles of other material, all in good condition.

E. Land Use

509 acres (16.6%) is < 0.5 dwelling units per acre urban residential, of which 5 acres (1%) is impervious.

151 acres (4.9%) is 0.5 to 2 dwelling units per acre urban residential, of which 10 acres (6.6%) is impervious.

574 acres (18.7%) is 2.5 to 8 dwelling units per acre urban residential, of which 103 acres (17.9%) is impervious.

319 acres (10.4%) is > 8 dwelling units per acre urban residential, of which 140 acres (43.9%) is impervious.

123 acres (4%) is Commercial, of which
97 acres (78.9%) is impervious.

14 acres (0.5%) is Industrial, of which
3 acres (21.4%) is impervious.

1005 acres (32.7%) is Parkland, of which
63 acres (6.3%) is impervious.

360 acres (11.7%) is Agriculture, of which
3 acres (0.8%) is impervious.

20 acres (1.6%) is Wetlands.

VIII. Catchment Name - MI3, TRAV CK DR OT

A. Area - 4402 acres.

B. Population - 8400 persons.

C. Drainage - This catchment area has a representative slope of 68.6 feet/mile, 18% served with curbs and gutters and 82% served with swales and ditches. The storm sewers approximate a 37.8 feet/mile slope and extend 25,700 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 41 lane miles of asphalt, 15% of which is in good condition and 85% of which is in fair condition. In addition there are about 17 lane miles of concrete, of which 100% is in good condition, and 18 lane miles of other materials, all in good condition.

E. Land Use

125 acres (2.8%) is < 0.5 dwelling units per acre urban residential, of which 6 acres (4.8%) is impervious.

161 acres (3.7%) is 0.5 to 2 dwelling units per acres urban residential, of which 7 acres (4.4%) is impervious.

174 acres (4%) is 2.5 to 8 dwelling units per acre urban residential, of which 32 acres (18.4%) is impervious.

192 acres (4.4%) is > 8 dwelling units per acre urban residential, of which 114 acres (59.8%) is impervious.

49 acres (1.1%) is Commercial, of which
38 acres (77.6%) is impervious.

96 acres (2.2%) is Industrial, of which
3 acres (3.1%) is impervious.

1530 acres (34.8%) is Parkland, of which
70 acres (4.6%) is impervious.

1862 acres (42.3%) is Agriculture, of which
130 acres (7%) is impervious.

213 acres (4.8%) is Forest.

IX. Catchment Name - MI3, TRAV CK RT BN I

A. Area - 2303 acres.

B. Population - 160 persons.

C. Drainage - This catchment area has a representative slope of 33.2 feet/mile, 100% served with swales and ditches. The storm sewers approximate a 28.5 feet/mile slope and extend 9,500 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 17 lane miles of asphalt, 100% of which is in good condition. In addition there are about 15 lane miles of concrete, of which 100% is in good condition, and 10 lane miles of other materials, all in good condition.

E. Land Use

125 acres (5.4%) is < 0.5 dwelling units per acre urban residential, of which 6 acres (4.8%) is impervious.

52 acres (2.3%) is 0.5 to 2 dwelling units per acre urban residential, of which 2 acres (3.8%) is impervious.

10 acres (0.4%) is Commercial, of which 3 acres (30%) is impervious.

37 acres (1.6%) is Industrial, of which 1 acre (2.7%) is impervious.

4 acres (0.2%) is Parkland, of which 1 acre (25%) is impervious.

1862 acres (80.8%) is Agriculture, of which 130 acres (7%) is impervious.

213 acres (9.2%) is Forest.

X. Catchment Name - MI3, TRAV CK RT BN OT

A. Area - 2327 acres.

B. Population - 160 persons.

C. Drainage - This catchment area has a representative slope of 33.2 feet/mile, 100% served with swales and ditches. The storm sewers approximate a 28.5 feet/mile slope and extend 9,500 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 17 lane miles of asphalt, 100% of which is in fair condition. In addition there are about 15 lane miles of concrete, of which 100% is in good condition, and 10 lanes miles of other materials, all in good condition.

E. Land Use

125 acres (5.4%) is < 0.5 dwelling units per acre urban residential, of which 6 acres (4.8%) is impervious.

52 acres (2.2%) is 0.5 to 2 dwelling units per acre urban residential, of which 2 acres (3.8%) is impervious.

10 acres (0.4%) is Commercial, of which 3 acres (30%) is impervious.

37 acres (1.6%) is Industrial, of which 1 acre (2.7%) is impervious.

28 acres (1.2%) is Parkland, of which 1 acre ((3.6%) is impervious.

1862 acres (80%) is Agriculture, of which 130 acres (7%) is impervious.

213 acres (9.2%) is Forest.

XI. Catchment Name - MI3, N CAMPUS DR OT

A. Area - 1541 acres.

B. Population - 2800 persons.

C. Drainage - This catchment area has a representative slope of 89.8 feet/mile, 46% served with curbs and gutters and 54% served with swales and ditches. The storm sewers approximate a 53.3 feet/mile slope and extend 15,500 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 29 lane miles of asphalt, 7% of which is in good condition, 93% of which is in fair condition, and 1 lane mile of other material, all in good condition.

E. Land Use

255 acres (16.6%) is 0.5 to 2 dwelling units per acre urban residential, of which 7 acres (2.7%) is impervious.

395 acres (25.6%) is 2.5 to 8 dwelling units per acre urban residential, of which 53 acres (13.4%) is impervious.

61 acres (4%) is > 8 dwelling units per acre urban residential, of which 32 acres (52.5%) is impervious.

250 acres (16.2%) is Commercial, of which 167 acres (66.8%) is impervious.

580 acres (37.6%) is Parkland, of which 34 acres (5.9%) is impervious.

XII. Catchment Name - MI3, ALLEN DR OUTLET

A. Area - 3,800 acres.

B. Population - 35,700 persons.

C. Drainage - This catchment area has a representative slope of 82.0 feet/mile, 79% served with curbs and gutters and 21% served with swales and ditches. The storm sewers approximate a 57.9 feet/mile slope and extend 11,200 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 123 lane miles of asphalt, 20% of which is in good condition and 80% of which is in fair condition. In addition there are about 11 lane miles of concrete, of which 100% is in good condition, and 9 lane miles of other material, all in good condition.

139 acres (3.7%) is 0.5 to 2 dwelling units per acre urban residential, of which 5 acres (3.6%) is impervious.

1682 acres (44.3%) is 2.5 to 8 dwelling units per acre urban residential, of which 318 acres (18.9%) is impervious.

390 acres (10.3%) is > 8 dwelling units per acre urban residential, of which 300 acres (76.9%) is impervious.

344 acres (9%) is Commercial, of which
300 acres (87.2%) is impervious.

65 acres (1.7%) is Industrial, of which
45 acres (69.2%) is impervious.

1180 acres (31%) is Parkland, of which
345 acres (29.2%) is impervious.

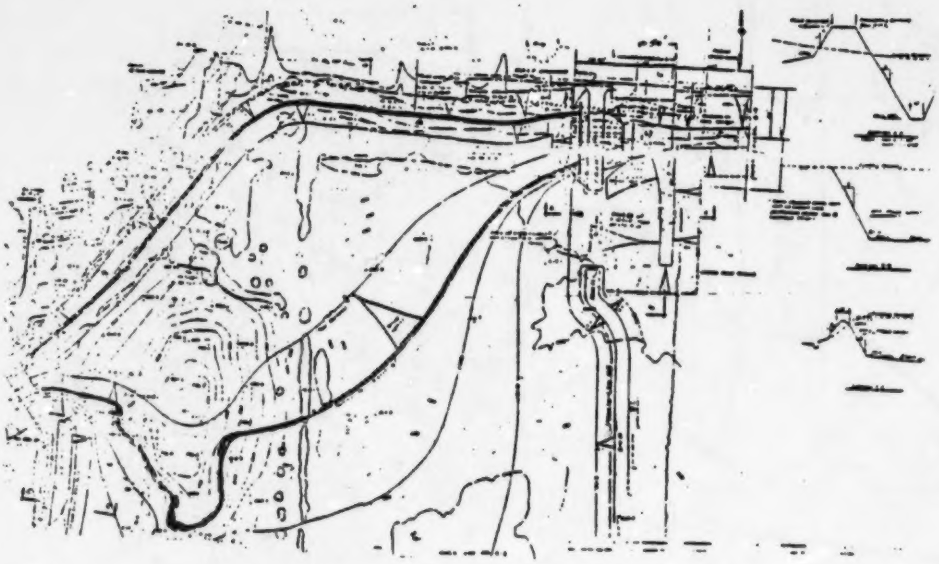
PROBLEM

A. Local Definition (Government)

The prior Section 208 study conducted in the Ann Arbor area by SEMCOG resulted in the determination that urban storm runoff introduced a significant amount of pollution into the receiving waters. Of three areas identified as needing additional monitoring and evaluation the specific reach covered under this project had the highest priority. The water quality background study on the Huron River Basin concluded that the most significant cause of poor quality water in the Huron in the Ann-Arbor-Ypsilanti reach was point sources and urban stormwater runoff. This reach has no point source discharges, and five major urban stormdrain discharges. State standards for ammonia and phosphorus concentrations and fecal coliform densities are exceeded.

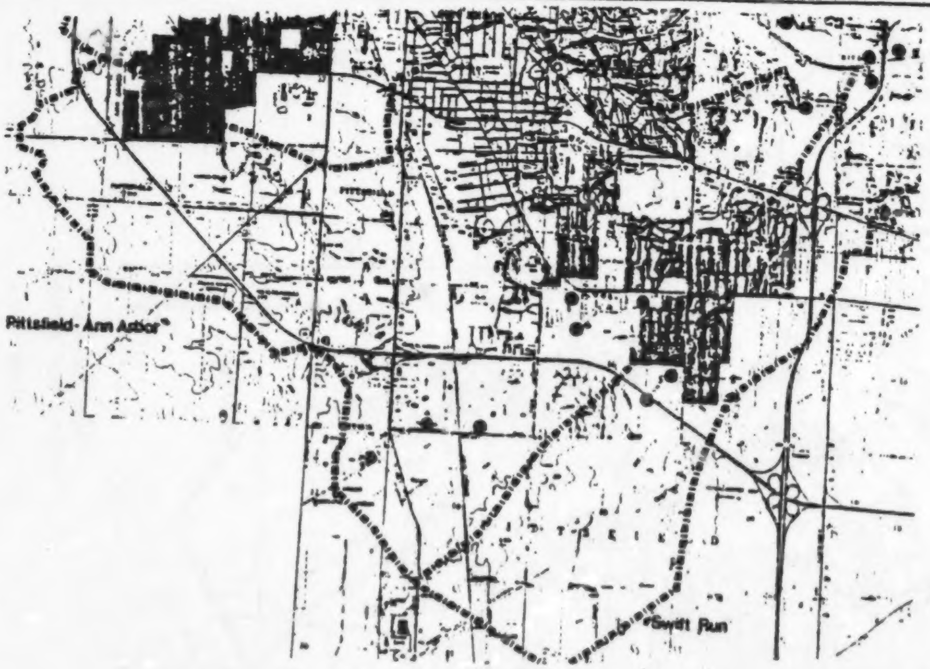
B. Local Perception (Public Awareness)

With the University of Michigan campus located adjacent to this reach of the Huron River, studies have been conducted at various times, and by various agencies of the water quality, primarily during dry weather flows. While this provides a good historical data base, as far as it may be applicable, it is not sufficient or of suitable types and quality to be used to evaluate wet weather conditions. However, such past studies have provided the public with information concerning the quality of the water in the Huron River. Both the community and the state consider the river to be a recreational resource. Boating on the Huron is popular, and city parks abut the river. State attempts at re-stocking to improve fishing have not resulted in the presence of popular game fish in the Ann-Arbor reach.



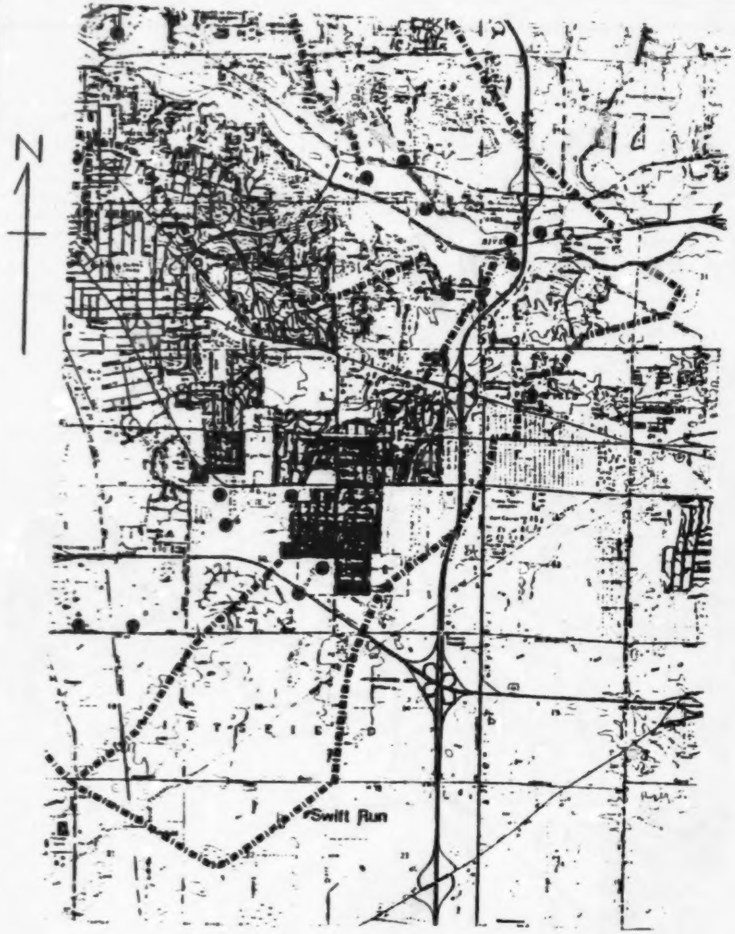
PITTSFIELD - ANN ARBOR DRAIN
RETENTION BASIN

FIGURE 4



PITTSFIELD - ANN ARBOR DRAIN
SAMPLING POINT LOCATIONS
FIGURE 3

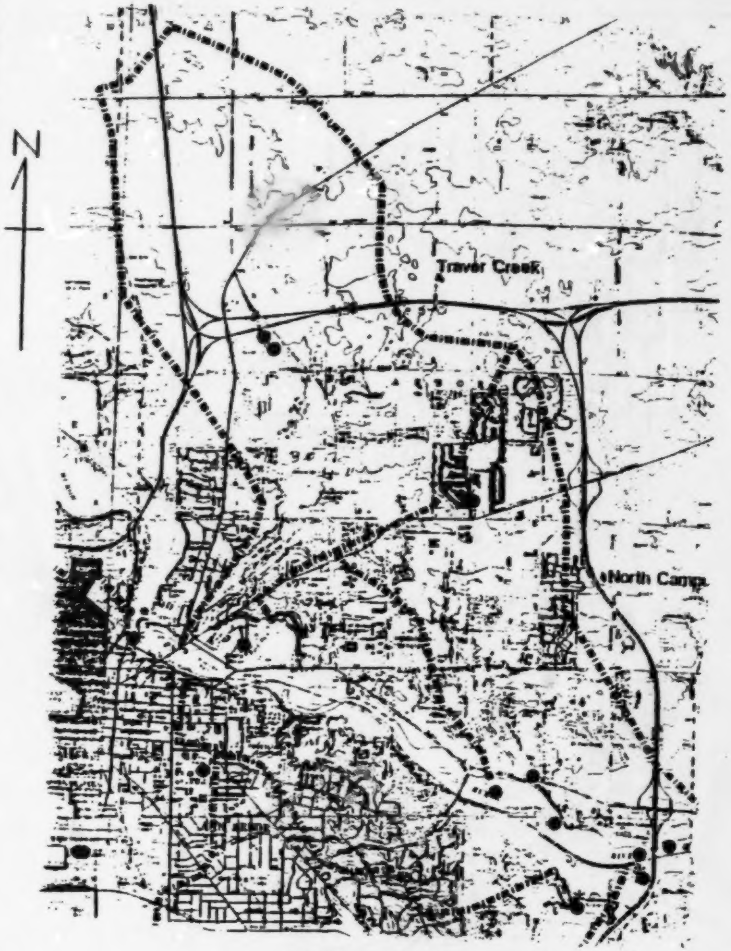
Reproduced from
best available copy.



SWIFT RUN DRAIN
SAMPLING POINT LOCATIONS

FIGURE 5

Reproduced from
best available copy.



TRAVER CREEK DRAIN
SAMPLING POINT LOCATIONS

FIGURE 6

PROJECT DESCRIPTION

A. Major Objective

Following the determination that the reach of the Huron River in Ann-Arbor was in need of pollution abatement, primarily from urban nonpoint stormwater runoff, an approach was developed to manage that source. Highlights included:

a. Preventing pollution from new development, accomplished through on and off-site retention and detention techniques.

b. Developing guidelines for the design and implementation of techniques for stormwater pollution abatement.

c. Subjecting major regional development projects to a review of stormwater pollution abatement.

d. For existing, builtup urban areas, developing guidelines for local units of government's uses. It is recognized that data on the cost-effectiveness of the measures to be considered does not presently exist, but that such data will be forthcoming from the Nationwide Urban Runoff Program.

e. Undertaking additional investigation and evaluation of stormwater pollution in Problem Areas. As mentioned above, this reach of the Huron River (Ann-Arbor-Ypsilanti) is the Problem Area requiring first attention. The focus of the additional work recommended is to quantify the costs and effects of the various control measures.

As part of the total NURP effort, this project has been planned to evaluate the utilization of selected best management practices for their effectiveness in reducing or preventing pollutant loads from urban runoff. This will at the same time improve the water quality of the Huron River to the degree that such techniques prove effective. This evaluation will require a sampling and monitoring effort during rainfall events, since most prior studies have been during dry weather.

B. Methodology

Major findings, reports, and presentations in the urban stormwater runoff area will guide project personnel, and their meaning in conjunction with project results will be summarized in the final project report. Additionally, data on the existing background conditions of the receiving streams and the Huron River, must be evaluated for the stormwater discharges for the purposes of this project. Much data has been developed on this reach of the Huron, which is a water quality limited reach, by many public agencies, universities and private contractors. An excellent historical data base exists therefore for selected aspects of the chemical, biological, and physical characteristics, but the data was collected for different purposes, by different geographic locations in the reach. Most all of the existing data has also been focused on conditions at selected locations during dry-weather, low flows for the purpose of establishing minimum stream flows neded to achieve water quality standards during such events. Attention to conditions during wet-weather high flows is a new concern and little if any data has been collected specifically for that purpose. It will be necessary therefore to acquire, condense, render and evaluate existing data on the Huron River in this reach in order to extract information reflective of wet-weather conditions. Developing such a profile using existing data will strengthen our analysis of the effect of BMP's under investigation on the receiving water.

Studies conducted within the last five years by a variety of agencies have with varying degree of sophistication examined stormdrainage flows from selected outfalls in the study reach. A brief survey of the available literature in journals will be made in order to determine relative loadings being observed elsewhere. Data existing on runoff entering this reach must be compiled and evaluated, compared with regional data from similar areas, and eventually compared with the results obtained in the monitoring which will be conducted in this project.

Essential land use/cover information must be compiled in order to compare the monitoring data from wet-weather events to the land features generating such runoff. One important objective of the research will be to observe the relationships, if any, between land use/cover and stormwater runoff. Existing land use data will be collected and evaluated and supplemented as needed to assure that a fine-scale of analysis will be possible. The result will be a land use/cover delineating within each Drainage District where a BMP is being investigated.

In addition to the sampling and monitoring program in the five drainage districts and the specific best management practices, precipitation data has been collected in the area. All sampling and monitoring for this project, which was scheduled to be completed in two years, has been completed. A final report will be completed during October 1981, and should be available about January, 1982.

C. Monitoring

The year one monitoring program included a sampling and analyses program to monitor water quality at the five storm drain outlets along the Huron River in the Geddes Pond area, in the river itself, and at inlet and outlet points at the BMP's. In addition precipitation quantity and quality information was measured as part of the program. Sediment chambers were placed in the river to obtain estimates of sedimentation rates in the study section of the Huron River. The second year monitoring program focused primarily on measuring water quality conditions at inlet and outlet locations at each BMP. Precipitation information was collected throughout the project period. Sediment chambers could not be located after two years in the river.

Monitoring stations were established during the first year's work at the inlets and outlets at the Pittsfield-Ann Arbor retention basin (wet, on-line basin) and the Swift Run Wetland. Monitoring stations at the inlet and outlet of the Traver Creek Retention Basin were established in the spring of 1981. However, due to construction delays in building the by-pass structure, the retention basin acted as an on-line retention basin during the study period. The by-pass structure was finished during the end of the summer of 1981.

Construction activities on the by-pass structure did not occur until after the completion of the monitoring program. Each station consisted of an automatic level recorder and automatic water sampler. Flow was determined by using the continuous level recordings in conjunction with site calibrated stage-discharge relationships. Water samples were collected individually at preset time intervals and then composited according to flow.

In addition to event monitoring, snow melt surveys were performed on the Pittsfield-Ann Arbor retention basin and the Swift Run Wetland. Second year rainfall event monitoring was conducted at the BMP's, including the Traver Creek on-line retention basin. This effect included collection of water quality samples and flow data for the inlet or (for Pittsfield-Ann Arbor), inlets and the outlet of each BMP.

During each runoff event flow was measured on a continuous basis by use of water level recording equipment and the use of a stage-discharge curve. The stage-discharge relationship was developed by measuring depth and velocity at several points to determine the curve. Once established, periodic checks of velocity-depth measurements were made during the survey work.

Flow proportionate composite samples were collected for chemical analyses. Individual grab samples using the automatic sampling equipment were composited manually into the flow weighted samples using the recorded level data and calculated flow rates. It has been our experience that two flow proportionate samples are generally required for inlet stations and three to five samples for outlet stations to adequately represent the inlet and outlet hydrographs and pollutant loadings. The outlet stations require additional samples due to the travel time required for the runoff waters entering the retention areas to pass through and exit the pond or wetland. Sampling of the initial discharge water represents the water quality, in the pond areas and during the heavy hydraulic loads, while post storm sampling at the outlet reflects inlet water reaching and passing the outlet structure.

During the first year of the study a continuous recording rain gauge at the University of Michigan provided rainfall information which was augmented by three manual rain gauges located in or near the districts being studied. A second recording rain gauge now in use was utilized during the second year of this study. This rain gauge is located at ENCOTEC's office which is in the Pittsfield - Ann Arbor Drain District and within one mile of the Swift Run Drain District. These two recording rain guages were utilized to document rainfall during the second year of this project.

Sediment chambers placed in the Huron River (Geddes Pond) during the first year of this program could not be found after two years in the river. Numerous attempts were made to locate the chambers but proved to be unsuccessful.

The first year analytical program showed that most of the parameters in the initial list should be retained for the second year program. The parameters to be monitored on all samples included:

pH
Alkalinity
Total Suspended Solids
Total Dissolved Solids
BOD$_5$ (Biochemical Oxygen Demand)
COD (sol, snol, Chemical Oxygen Demand)

Total Kjeldhal Nitrogen (sol, insol)
Nitrate
Phosphorus (sol, insol)
Irpn (sol, insol)
Lead (sol, insol)
Particle Size

One half of the samples

Grease and Oil
Cadmium
Zinc
Chromium
Fecal Coliform

The main changes in the analytical program from year one included the addition of chemical oxygen demand, and the elimination of nickel and copper from the list. COD was added because of the seemingly highly variable nature of the BOD levels monitored in the various drains. The COD test added another determination for organic type materials in the water to use along with BOD data. Nickel and copper were dropped from the program for the second year as the level of these metals was low in the first year surveys.

Equipment

Sampling was accomplished with automatic sampling equipment taking discrete samples which were subsequently composited manually as desired for specific analytical work. Precipitation was measured with continuous recording rain gages. Sampling and analysis was done by consultant contractor personnel.

Controls

The controls evaluated included the runoff ordinance, a detention/retention basin, and a naturally-occurring wetland. The description of these controls, and the Drains where they were located follows:

a. Traver Creek Drain - 1,513 acres are drained by this drain. Urban development is concentrated in the 200 acres surrounding the mouth of this watercourse. The stormdrains are located in this area and are physically separate from the sanitary lines. The flood plain of the drain is developed with multiple family structures and the drain is open its entire length. Rural and agricultural cover predominate in the balance of the district. Wet and dry weather surveys were conducted by the Drainage District in 1977-78.

The BMP investigated in this district was the runoff ordinance. Data on land cover and wet and dry weather stormwater runoff were collected during 1978 and can be used with the river mass balance data to compile the estimated effectiveness of a stormwater runoff ordinance enacted by the City of Ann-Arbor in 1977. Estimates of the existing and projected quantity of pollutants associated with future development can be determined and the reduction in loadings calculated. The impact on the river can be forecast thereafter.

An additional aspect to be documented will be the reasons for the ordinance's being rescinded by the City Council in early 1978. In this district both technical and political-economic data can be used to document and evaluate the reductions and costs associated with this BMP. Using relationships to be developed in this District it would also be possible to suggest the pollutant loadings which could be achieved throughout the City if the BMP were applied. A discussion and analysis of the institutions and technical constraints will also be prepared.

b. Pittsfield-Ann Arbor Drain - Open and agricultural cover in the upper portion of this district contribute runoff which passes through a regional shopping center and airport, a major commercial area and finally through sub-divisions containing single family dwellings. The confluence with the river is in Geddes Pond. Recently completed drainage improvements (1978) included enclosing some reaches and the creation of a major detention basin for hydrological purposes.

c. Swift Run Drain - This 1,716 acre tributary to the Huron River also joins the river at Geddes Pond which is a major recreation area developed by the City of Ann Arbor. Urban land cover is concentrated in the lower third of the district which is also below the naturally occurring wetland. The City's landfill is sited 1,000 feet upstream of this area. An analysis of the water quality impacts of the landfill was performed in 1975, and wet and dry weather conditions of the drain were documented for the district in 1978.

The BMP investigated was the capability of natural wetlands to reduce TSS, BOD and nutrients contained in stormwater runoff from urban cover. An initial data base was developed on this capability during the 1977 evaluation but only on one wet-weather event. This investigation determined the performance of the wetland during major seasons of the year. Net annual as well as seasonal impact of the wetland on pollutant loadings released to the river was determined. Other data collected on this district were pollutants introduced by precipitation patterns during selected storm events, and wet-weather samples at the mouth during spring melt and late summer 1978.

NATIONWIDE URBAN RUNOFF PROGRAM

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY AND
ILLINOIS STATE WATER SURVEY DIVISION

CHAMPAIGN, IL

REGION V, EPA

INTRODUCTION

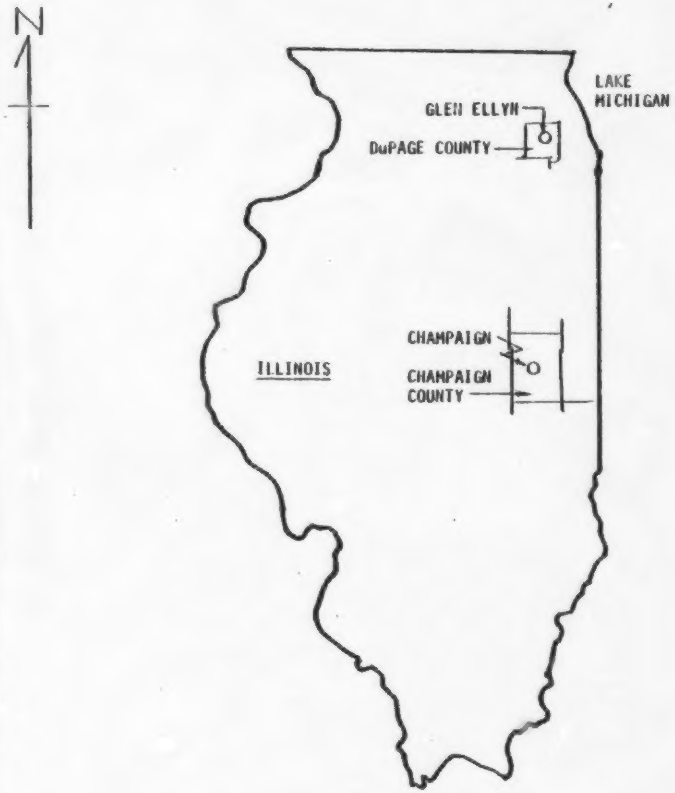
The City of Champaign, situated in Champaign County, is located in mideastern Illinois, about 120 miles south of Chicago, and about 40 miles west of the Indiana state line. Topography in the study area consists of gentle slopes, served by urban feeder creeks.

The major urban drainage basin in the study area is Boneyard Creek, and the other area drainage basin is Copper Slough and the Finny Branch of the Kaskaskia River. Both of these drainages are included in the category of Illinois rivers and streams designated for general use. The alternate category, to which certain named rivers and streams are assigned and which is not applicable in the project area, is designated for secondary contact and indigenous aquatic life waters.

Central Illinois agricultural development included substantial tile drainage installation due to the existing swampy conditions. The center of Champaign-Urbana is located on a small hill and drainage is away from the downtown area. Boneyard Creek, which carries flow from the downtown area and tile drains, flows into Saline Ditch, at which point sanitary treatment plant discharges are located. Saline Ditch flows into the Saline Branch of the South Fork of the Vermillion River. Flow continues into the Wabash River, the Ohio River, and finally into the Mississippi River. Flow from Copper Slough and Finny Branch enter the Kaskaskia River, and eventually the Mississippi River.

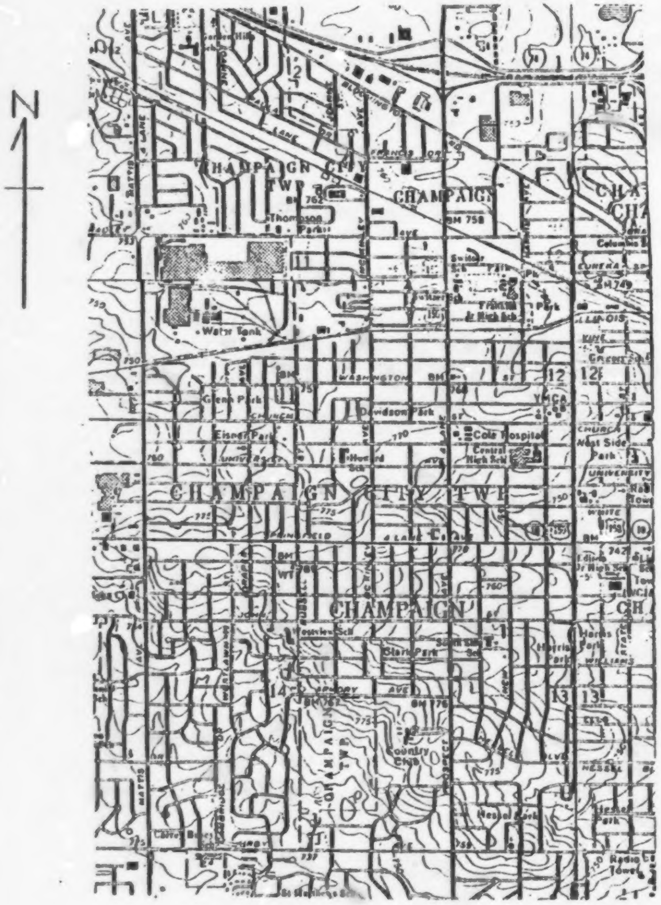
Historically, the Champaign-Urbana, Illinois, standard metropolitan statistical area (SMSA) population has grown from 106,414 in 1950 to a figure of 168,392 obtained in the 1980 census, an increase of 58% in thirty years. During the 10 years from 1970 to 1980, census figures show an increase from 163,281 which is only 3.1%. The 1970 census population of Champaign was 56,532, reported as an increase of 14% from 1960. The comparable 1980 figure is 58,133, which is an increase of 3% during the past ten years. The Department of Commerce 1972 Series E OBERS projection for the SMSA for 1980 was 177,400, 9,000 more than was actually experienced. The difference in rate of growth projected and experienced indicates a slowing down in the increase in both the SMSA and the Champaign urban area to approximately 3%.

Public concern about the pollution effect of urban stormwater runoff relates to costs of control, and the possibility that agricultural runoff may be an equally important source of pollution to the feeder creeks. Determination of the cost and effectiveness of the street sweeping control will be followed up by a study of receiving water impacts in the last year of the project.



STATE LOCUS
ILLINOIS NURP PROJECTS

FIGURE 1



CHAMPAIGN STREETS
USGS QUAD SHEET
FIGURE 2

Reproduced from
best available copy.

PHYSICAL DESCRIPTION

A. Area

The City of Champaign situated in Champaign County, is located just West of and contiguous to the City of Urbana, in the mid-east part of the state of Illinois approximately 40 miles West of the State of Indiana on interstate route 74, as shown in Figure 1. The total area of the city comprises about 11.4 square miles. Land use within the city is characterized as residential and commercial, with some agricultural areas. Figure 2 shows street layout in the vicinity of the monitored streetsweeping areas.

B. Population

The rate of growth of population in the Champaign-Urbana Standard Metropolitan Statistical Area, and in Champaign, itself, has approximated 3% between the 1970 and 1980 census polls. Projecting this rate of growth to the years 1990 and 2000, the 1980 figure of 58,133 will become 59,000, and then 61,670 respectively. This is a lower rate of growth then experienced during the last 30 years, when SMSA population grew by 58%, but is more realistic than applying the larger percentage figure.

C. Drainage

The topography in Champaign-Urbana is best described as gently rolling, with the urban center located on a small hill, and with drainage away from the downtown area. As noted in the introduction, drainge is conducted by local streams to regional rivers, eventually being carried to the Mississippi River.

D. Sewerage System

The City is 100% served with a separate sanitary sewer system with the treatment plant discharge to Saline Ditch. The urban area is served by curbs, gutters, storm drains and the local streams.

PROJECT AREA

I. Catchment Name - B 01, Mattis Avenue No. Basin 1

A. Area - 16.66 acres.

B. Population - 50 persons.

C. Drainage - The representative slope of the catchment is 18.7 feet/mile, with a representative storm sewer slope of 28.4 feet/mile, extending a total of 3,255 feet.

D. Sewerage - The catchment area is completely served with separate storm sewers with curbs and gutters.

There is approximately 0.3 lane miles of asphalt roads, all in fair condition, and approximately 2.4 lane miles of concrete road, all in fair condition.

E. Land Use

7.15 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 2.25 acres (31%) is impervious.

9.51 acres (100%) is Linear Strip Development, of which 7.44 acres (78%) is impervious.

Approximately 58% imperviousness in entire catchment area.

II. Catchment Name - B 02, Mattis Avenue South Basin 2

A. Area - 27.6 acres.

B. Population - 600 persons.

C. Drainage - This catchment area has a representative catchment slope of 54.9 feet/mile, and 57.6% with curbs and gutters and 42.4% with swales and ditches. The storm sewers approximate a 63 feet/mile slope and extend 2,480 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 0.23 lane miles of asphalt in good condition, and 2.10 lane miles of concrete - 80% in good condition and 20% in fair condition.

E. Land Use

19.26 acres (78%) is 2.5 to 8 dwelling units per acre urban residential, of which 4.8 acres (25%) is impervious.

5.59 acres (22%) is > 8 dwelling units per acure urban residential of which 2.78 acres (68%) is impervious.

2.78 acres (100%) is Linear Strip Development, of which 2.5 acres (90%) is impervious.

Approximately 40% is imperviousness in entire catchment area.

III. Catchment Name - B 03, James and Daniel Basin 3

A. Area - 1.38 acres.

B. Population - 30 persons.

C. Drainage - This catchment area has a representative catchment slope of 90 feet/mile and 100% curbs and guttes. The storm sewers approximate a 90 feet/mile slope and extend 350 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

This micro-basin includes 0.11 lane miles of concrete streets, all classified in fair condition.

E. Land Use

1.38 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 0.19 acres (14%) is impervious.

IV. Catchment Name - B 04, John Street South Basin 4

A. Area - 39.2 acres.

B. Population - 720 persons.

C. Drainage - This catchment area has a representative catchment slope of 62 feet/mile, and 91% curbs and gutters and 9% swales and ditches. The storm sewers approximate a 69 feet/mile slope, and extend 2,530 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Street consist of 0.23 lane miles of asphalt in good condition, and 3.1 lane miles of concrete, 20% in good condition and 80% in fair condition.

E. Land Use

35.6 acres (90.9%) is 2.5 to 8 dwelling units per acre urban residential, of which 6.84 acres (19%) is impervious.

3.6 acres (9.1%) is Urban Parkland or Open Space, all pervious.

V. Catchment Name - B 05, John Street North, Basin 5

A. Area - 54.4 acres.

B. Population - 1,000 persons.

C. Drainage - This catchment area has a representative slope of 30.6 feet/mile, and 100% curbs and gutters. The storm approximate sewers a 35.5 feet/mile slope, and extend 3,260 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 1.7 lane miles of asphalt in good condition, and 3.0 lane miles of concrete, of which 10% is in good condition, 80% is in fair condition, and 10% is in poor condition.

E. Land Use

54.4 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 10 acres (18%) is impervious.

PROBLEM

A. Local Definition (Government)

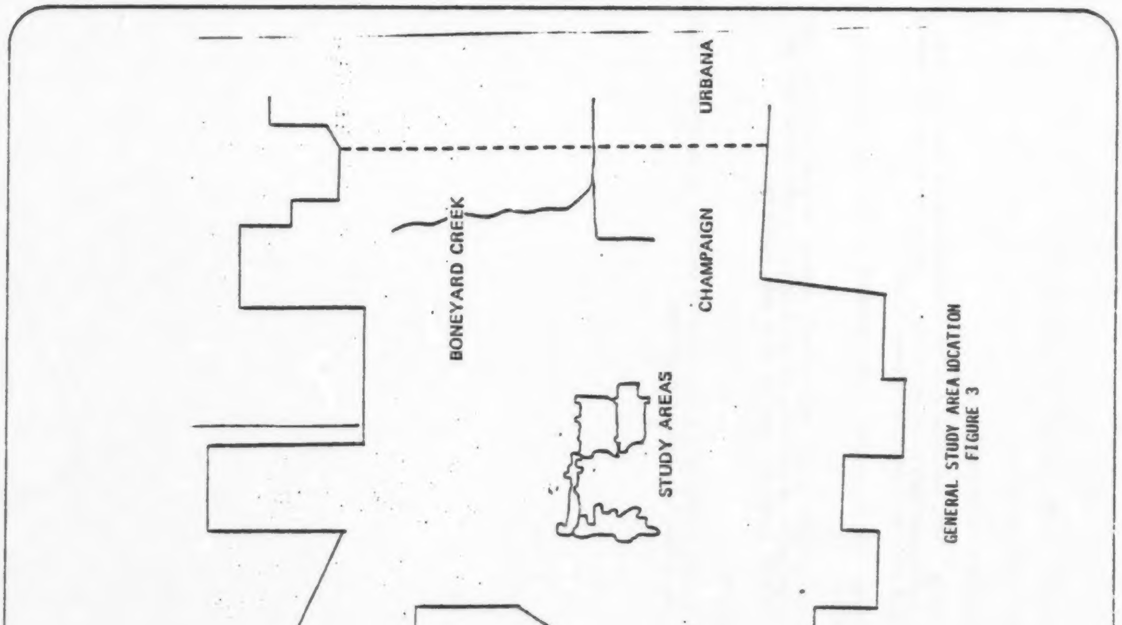
Previous studies conducted by the Illinois State Water Survey focussed on water quality standards violations. Conclusions reached included evidence of frequent and excessive standards violations occurring during stormwater runoff, which were for short periods of time.

The problem is that there is only very limited data on (1) the effectiveness of streetsweeping in controlling pollution from urban stormwater runoff, (2) the most cost-effective streetsweeping program to adopt, and (3) what happens to pollutants transported into the receiving water body. A plan of development of a creekside park is coupled with a major area redevelopment.

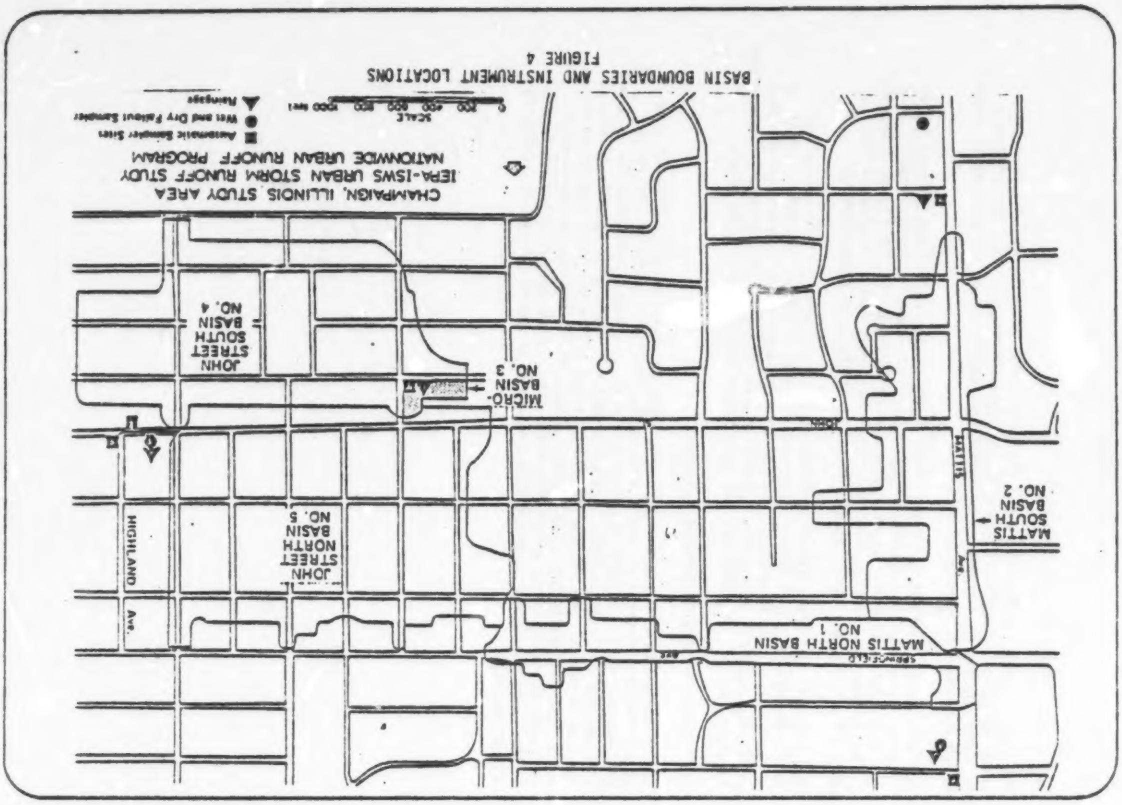
The Illinois Environmental Protection Agency is planning to examine urban receiving stream point source discharges versus nonpoint sources. The study area feeder creeks discharge into larger waterways which collect runoff from, primarily, agricultural areas. A better understanding of the interrelationships of these sources of pollutants is expected as one result of the study.

B. Local Perception (Public Awareness)

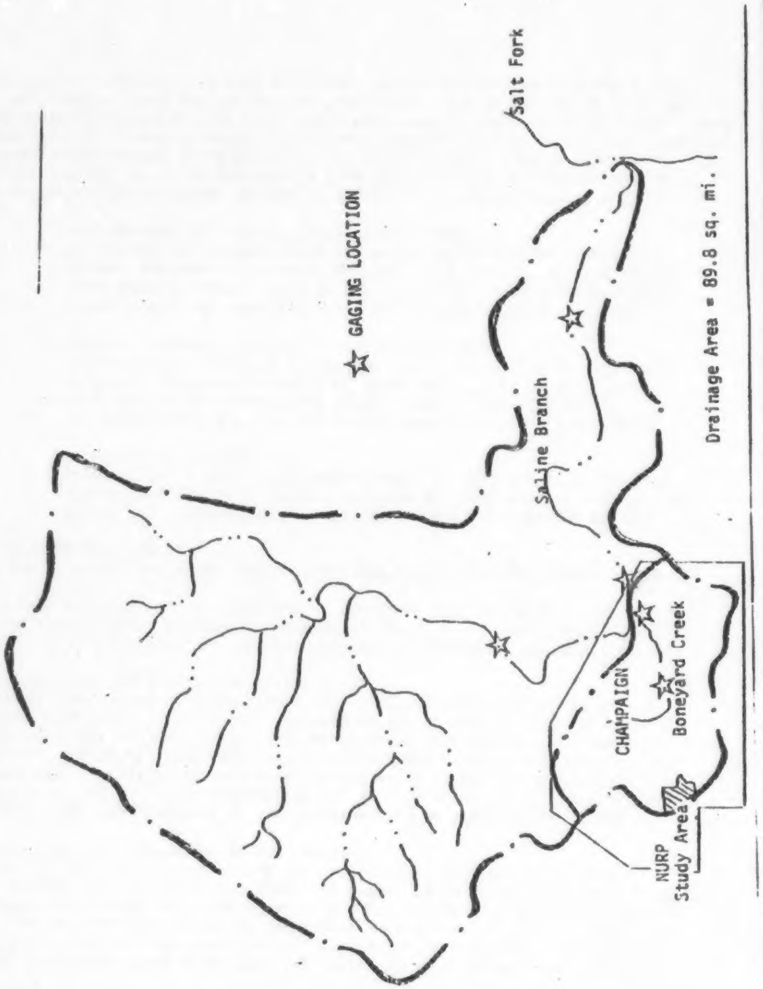
Local residents have expressed varied concerns about stream pollution from urban runoff. Generally, while some would like to see opportunities for fishing and water contact, there is not a large concern expressed to up-grade the quality of feeder creeks. Concern does not exist with respect to cost of control measures, and the feeling is that agricultural runoff may be an even more important pollutant contributor. The public interest in the area is centered on maintaining acceptable water quality in the recreational lakes, rather than the urban drainage streams, where concerns related basically to flood control.



GENERAL STUDY AREA LOCATION
FIGURE 3


CHAMPAIGN, ILLINOIS STUDY AREA
IEPA-ISWS URBAN STORM RUNOFF STUDY
NATIONWIDE URBAN RUNOFF PROGRAM
Automatic Sampler Sites
Wet and Dry Fallout Sampler
Raingage
SCALE
0 200 400 600 800 1000 feet
JOHN STREET SOUTH BASIN NO. 4
MICRO-BASIN NO. 3
JOHN STREET NORTH BASIN NO. 5
MATTIS NORTH BASIN NO. 1
MATTIS SOUTH BASIN NO. 2
HIGHLAND Ave.
MATTIS Ave
SPRINGFIELD Ave
JOHN

BASIN BOUNDARIES AND INSTRUMENT LOCATIONS
FIGURE 4



BASIN BOUNDARY AND GAGING LOCATIONS
FIGURE 5

Project Description

A. Major Objective

One of the problems identified in previous 208 urban area studies was that of pollution from stormwater runoff causing water quality standards violations. This project was designed to evaluate municipal street sweeping as a potential best management practice to control urban stormwater pollution of the receiving streams.

The first year effort resulted in site selection, selection, purchasing and installation of monitoring equipment, and initiating a streetsweeping and monitoring and sampling program. Computer model modification, also was initiated during the first year. The second year of the project included a continuation of the monitoring and sampling program, model modification, and initiation of data analysis, which is still underway. Over 6,000 samples have been collected and analyzed. Third year sampling will focus on receiving waters. Simulations using the modified model will be correlated with actual results at monitoring stations. Modeling is being applied as an economic way of evaluating the urban impact, for which an adequate monitoring and sampling program would be prohibitively expensive.

The goals anticipated to be met include:

1. Relating the accumulation of street dirt to such factors as land use, traffic count, time, type and condition of surface;
2. Defining street dirt washoff in terms of rainfall rate, flow rate, available material, particle size, slope and surface roughness;
3. Determining what fraction of pollutants occurring in stormwater runoff come from atmospheric fallout;
4. Modifying the Q-ILLUDAS model to permit examination of the functions determined above; and
5. Evaluation of the runoff impact from urban nonpoint sources on the receiving waters.

B. Methodologies

The streetsweeping studies are being conducted in the five small urban basins identified in Figure 4. Data collected include continuous measurement of rainfall and runoff, chemical analysis of rainfall and runoff, chemical analysis of dry atmospheric fallout, accumulation rate of street dirt, particle size distribution of street dirt and chemical analysis of street dirt.

One of the five basins consists of about 0.1 acre of street area contributing to a single inlet and will be referred to as the micro-basin. Since no pipe flow is involved in this basin, data from it will be used to examine the washoff characteristics of surface flow. The exponential washoff functions used in most current models have been shown to be inadequate for accurate simulation of the washoff function (2). Two of the remaining four basins are similar in size and have a uniform land use consisting of single family residential. The final two basins are similar in size and consist primarily of heavy traveled 4-lane streets serving a commerical area.

After an initial clean up by the city including sweeping and flushing of the streets and cleaning of catch basins, all basins were allowed to accumulate dirt without municipal sweeping while data collection took place. This accumulation period consisted of about 9 weeks in the fall and winter of 1979 and 15 weeks in the spring and summer of 1980. The data collected during this period allowed for calibration of the QUAL-ILLUDAS model on all 5 basins without the complication of street sweeping.

In July 1980, the municipal street sweeping program began on one of the residential and one of the commercial basins. These two basins were designated as the experimental basins and were cleaned twice weekly by the municipal sweeper. The other residential and commercial basins were maintained without sweeping as the control basins. The micro-basin lies within the residential control basin and was not swept. Throughout the 24 week control period and the municipal sweeping period street dirt sampling continued on all basins to monitor the accumulation of street dirt.

A concurrent activity during the data collection period was the modification of the ILLUDAS model to simulate washoff by particle size and runoff quality on a continuous basis. This version of the model will be known as Q-ILLUDAS.

The actual evaluation of municipal street sweeping is accomplished by three independent techniques:

1. Street dirt sampling before and after municipal sweeping provides a basin wide sweep or removal efficiency. Knowledge of the chemical composition of this street dirt permits calculation of the amount of pollutant removed.

2. Continuous simulation of the accumulation, sweeping, and washoff functions using a calibrated model. This is the most flexible method of evaluating sweeper performance in terms of water quality improvements. Specific pollutants can be considered as well as specific sweeping frequencies and efficiencies.

3. Comparison of the chemical analyses of runoff from control versus experimental basins. This is the most direct method of relating sweeper performance to water quality. The validity of this method is improved by demonstrating the degree of similarity between the experimental and control basins with a model.

Evaluation of the pollutant impacts of the urban stormwater runoff on the receiving water, to be accomplished during the third year of the project, will include both sampling and modelling. The proposed study site is shown in Figure 5. The receiving water associated with this study is a small agricultural stream with a watershed area above the urban input of about 68 square miles. Much of the basin is tiled and the stream channelized. The stream bed at sampling locations is only 20 to 30 feet in width. This configuration will allow the

use of single point automatic samplers with only occasional vertically and horizontally integrated samples for calibration. The small size of the stream will further simplify measurement of sediment oxygen demand, the collection of representative sediment cores, and the conducting of bio-assays. All water sampling can be done from small bridges reducting required personnel, increasing their response time, and eliminating the need for special equipment such as boats.

The agricultural watershed is about ten times the size of the urban watershed contributing to it. The response time of the agricultural watershed is nearly 20 times that of the urban contributions. This is a desirable ratio since the impact of the urban runoff will be significantly different for a thunderstorm than it would be for a frontal type rainfall. One of the goals of the project will be to relate urban impact to type of rainfall and season.

The problems inherent in mathematical modeling for urban impact analysis will be overcome in two ways. First, a comprehensive sampling program on the receiving water will eliminate the need for instream simulation. All results will be based on hard data and observed event. Secondly, simulation within the urban area will be limited to changes in loading related to hypothetical municipal street sweeping intensities. Further, the Q-ILLDAS model to be used for this simulation was developed on data from this basin and will be calibrated for each observed event used in the analysis of data. The proposed combination of data collection and simulation takes advantage of the strongest aspects of each and will lead to the most reliable results possible from such a study.

A comprehensive data collection program will be used to establish the quantity and quality of dry weather and wet weather flow for a small agricultural basin upstream from and downstream from a significant urban contribution. The impact of the urban contribution on measurable water quality parameters will be the difference between these upstream and downstream observations. Loading of the stream from the urban portion of the watershed will be measured as part of the data collection program and simulated using the Q-ILLUDAS model. The effect of municipal street sweeping upon the quality of urban runoff and the impact of that runoff on the receiving stream will be demonstrated by simulating the reduction of loading from the urban area as a result of various intensities of municipal sweeping.

Existing conditions in the stream, upstream and downstream from the urban contribution will also be documented. In addition to the actual measured water quality parameters, these conditions will include: the diversity of micro-organisms and fish, the sediment oxygen demand of the stream bed, the biological and chemical composition of the stream bed, public use and perception of the stream, mathematical relationships between various stream dimensions known as stream geometry, bank stability and condition, and vegetative cover of the banks.

C. Monitoring

The monitoring program covers five in-town sub-catchment areas and the larger drainage catchment that includes Saline Branch and its tributaries. The catchments have been described in proceeding sections and are outline in Figures 4 and 5, which also indicate the monitoring equipment locations.

Following is the maximum list of constituents. Water samples will average 15 analyses per sample, rainfall samples will receive an average of 10 analyses, and sediment samples will average about 12 routine analyses.

Total Dissolved Solids	
Total Volatile Suspended Solids	
Total Solids	
pH	
Specific Conductance	
Nitrate plus Nitrite (as N)	Dissolved, Total
Ammonia Nitrogen (as N)	Dissolved, Total
Kjeldahl Nitrogen (as N)	Dissolved, Total
Phosphorus (as P)	Dissolved, Total
Lead	Dissolved, Total
Copper	Dissolved, Total
Iron	Dissolved, Total
Zinc	Dissolved, Total
Mercury	Dissolved, Total
Chromium	Dissolved, Total
Cadmium	Dissolved, Total
Manganese	Dissolved, Total
Chloride	
Sulfate	
Organic Carbon (as C)	Dissolved, Total
Chemical Oxygen Demand	
Biochemical Oxygen Demand	5-day, Ultimate
Fecal Coliform Bacteria	
Fecal Streptococcal Bacteria	
Temperature	
Dissolved Oxygen	
Color	
Turbidity	
Hardness	
Particle Size Determination	

Occasional special constituents: PCB's, Pesticide, Herbicide Scans.

Rainfall and sediment samples will be limited to metals and nutrients.

Equipment

This discussion is in two parts, covering the streetsweeping portion conducted during the first two years first, followed by the receiving water impact assessment effort. In general, flow measurement and sampler control at all five basins and raingages at three locations are tied into a telemetry system. In addition to the equipment purchased for this project, three wet-dry samplers and one recording raingage are on loan from ISWS. Other equipment described is for use in the street dirt sampling and sieving process.

A decision was made at the time that the original proposal was written to utilize telemetry in the data collection network. The heart of a telemetry network is a mini-computer with a typewriter style keyboard for input, a printer for output, and magnetic storage on cassette tape or floppy disk. These items can all be placed on a desk top in a convenient location and are referred to as the central or central station. The central station is connected by leased phone lines to one or more remote stations. A remote station is an electrical device that can receive signals from raingages, depth sensors or temperature sensors and communicate these signals back to the central. The remote station can also start up electrical devises such as pumps or motors on command from the central. The remote station must be wired directly to the devices with which it communicates or which it controls. For this reason the remote station is usually located within a few hundred feet of these various devices.

Some advantages of a telemetry system in this kind of a project are:

1. All raingages, depth sensors and samplers operate on a single clock located in the central station. Synchronization of data is automatic and precise.
2. Data is recorded directly into magnetic storage eliminating the chart reading operation.
3. Status checks of the instruments are made automatically every 60 minutes, 24 hours a day. The system can also be checked or operated from the office. This helps to avoid instrumentation being down when an event occurs.
4. Event simulations can be compared with observed values after an event has occurred.
5. Additional cost of equipment is offset by reduction in manpower.

Disadvantages include the reliance upon a number of manufacturers for pieces of equipment that must interface electrically with each other. A further disadvantage is the necessity for a highly skilled individual to set up, program, and trouble-shoot the system. In addition, equipment breakdown/malfunction and power outages may occur during a significant storm event, which will consequently not be monitored.

Central Station --

1. Computer - Heath H-11A with 32K RAM, a real time clock, and BASIC language compiler.
2. Input/Output - A Texas Instruments model 745 hard copy data terminal.
3. Storage - Heath dual floopy disk system with controller and operating system. Each standard 8 inch disk contains 256 K bytes of storages.
4. Interface - EMR Recon II Number 3283 from Sangamo Weston. This is a device capable of receiving phone line signals from and transmitting signals to a remote station.

Remote Station --

Recon II remote Sangamo Weston, a device capable of receiving hard wire signals with at least 8 separate addresses of the following types:

1. Status/Alarm: 8 Status/Alarm inputs for relay closure.
2. Analog: 6 points, 0 to 5V, 0-4ma, and 4-20ma, 8 bit coding accuracy through the central station ± 0.5% or better.
3. Control: 4 two-state or 8 unitary controls, contact closure rated at least 200ma and 30 volts for 200ma.
4. Pulse Accumulator: accepts on tipping bucket raingage signal and provides accumulation of up to 255 pulses before reset-capable of interrogation at anytime without affecting count - two registers to prevent overflow.

Four of these remote stations were required to provide communication with all of the raingages, depth sensors and samplers in the network.

Bubbler (Flow Measurement) --

Flow measurement is accomplished by measuring depth of flow approaching a control section. The control section can be created by installation of a partial restriction to flow in the pipes or can occur at a free overfall section. Both of these methods are utilized. The device selected to measure depth is the Sigma-motor LMS-300 level recorder. It operates on 110 volt AC, has its own compressor and has an accuracy of ± 1% or better in an operating range of 0 to 3 feet of head. The bubbler outputs a 4-20ma signal to the telemetry remote. The signal is proportional to the pressure required to force a bubble of air through an orifice located at the invert of the storm sewer. That pressure is in turn proportional to the depth of flow over the orifice. The LMS-300 is also equipped with a small chart recorder which is used for backup and to check the instrument's performance in the field.

Automatic Sampler --

The automatic sampler must be able to withdraw a sample of water from the storm sewer on command from the remote station and store this sample of water in a refrigerator until it can be picked up and transported to the laboratory. The unit used in this study is the Sigma-motor 6301 refrigerated sampler. Upon receiving a signal to take a sample the 3/8 inch suction line is air purged, a sample is pumped, the line is purged again, and the sampler positions itself for the next sample. Samples are limited to 24 500ml bottles. A peristaltic pump is used so that the sample only contacts the Tygon tubing and the latex tubing used in the suction line.

Equipment Shelter --

At each of the sampling points the remote station, one or more bubblers, and the automatic sampling device are housed in a two-door fiberglass shelter approximately 4 feet square and 4.5 feet tall. The shelter is a Western Power Model 42-2. It has one inch of from insulation and a thermostatically controlled exhaust fan for temperture control in the summer.

Raingages --

Three Weather Measure P-501 tipping bucket raingages are part of the telemetry network. The 8 inch diameter collector funnels the rainwater to a dual cup device that holds 0.01 inch of water. As one of these cups fill the device tips to empty one cup and begin filling the other cup. The tip causes a switch closure which is transmitted to an accumulator in the remote as 0.01 inch of rain.

Wet-Dry Fallout --

These devices were produced by and are on loan from the ISWS. Similar devices are available commercially. Two plastic buckets are installed on a frame about one meter above the ground. A lid covers one of these buckets and exposes the other to dry fallout. A sensor on the lid detects rain and the lid moves to cover the dry fallout bucket and expose the other bucket to catch a rainfall sample. After rainfall ceases the lid again moves and exposes the dry fallout bucket.

Street Dirt Sampling Equipment

Samples of street dirt are collected by running a shop type vacuum cleaner over selected strips of pavement from curb to curb. This procedure requires a vacuum, a generator, and a vehicle to move this equipment from site to site. Additional equipment is required for sieve analysis of the sample upon returning to the lab.

Vaccumm --

A Hild Model 730 Industrial Vacuum consisting of a 30 gallon stainless steel tank, a 2.3 hp motor, 20 ft of 2 inch vinyl hose, a 4 foot aluminum wand with a 12 inch floor tool and a dynel cloth filter (cotton/nylon blend).

Generator --

A Lincoln Model K-1282 Welder-Generator with a Kohler Model K-241P 10hp engine rated at 4500 watts AC.

Truck --

The Vacuum and Generator are mounted in a 1980 Dodge Van equipped with a yellow strobe light for safety.

Sieving --

Stainless Steel sieves by W.S. Tyler were used on a Combs Type HL Gyratory Sifting Machine. It is made by Great Western Manufacturing Co. and is equipped with a 1/6 hp motor.

The receiving water impact study equipment, and its purposes are described as follows:

1. Flow Measurement -- Flow measurement at all sites except the UCSD outfall will be determined by continuously monitoring depth of flow at a rated section. Depth of flow will be determined with a float, bubbler, or ultrasonic device depending on available equipment. On the Boneyard Creek sites these devices will be tied to the telemetry system. On the Saline Branch sites the devices will record on independent clock driven charts. Rating curves will be established or checked by current meter measurements throughout the period of study.

2. Rainfall -- Three tipping bucket rain gauges in the urban watershed will be supplemented by two weighing bucket recording gauges in the agricultural watershed.

3. Atmospheric Sampling -- Automatic wet/dry fallout samplers will be operated at two locations, one in the urban area and one in the agricultural area. Rainfall will be analyzed for nutrients and metals for each event.

4. Present Stream Conditions -- Biological assays, measurement of sediment oxygen demand, and sediment core sampling will be done on a seasonal basis. This information along with documentation of bank stability and vegetative cover will provide an up-to-date evaluation of the receiving stream condition during the year of the study.

5. Water Samples -- Dry weather samples will be collected monthly at all six sampling points and analyzed for the constituents indicated below. Each of the sampling points except the UCSD outfall will be equipped with automatic samplers. Samplers on the Boneyard will be on the telemetry network and will sample on a 5 minute interval. Samplers on the Saline will be triggered on a rise in stage and will sample on a 15 to 30 minute interval. An attempt will be made to collect discrete samples on 15 to 20 storm events during the 8 month sampling period.

In addition to the automatic sampling, augmentation will be by manual sampling. This will consist of horizontally and vertically integrated samples collected with a DH59 sampler equipped with a glass bottle.

Controls

As previously described, this project will be evaluating streetsweeping as an effective best management practice for control of urban stormwater runoff pollution of receiving waters.

NATIONWIDE URBAN RUNOFF PROGRAM

NORTHEASTERN ILLINOIS PLANNING COMMISSION

CHICAGO, IL

REGION V, EPA

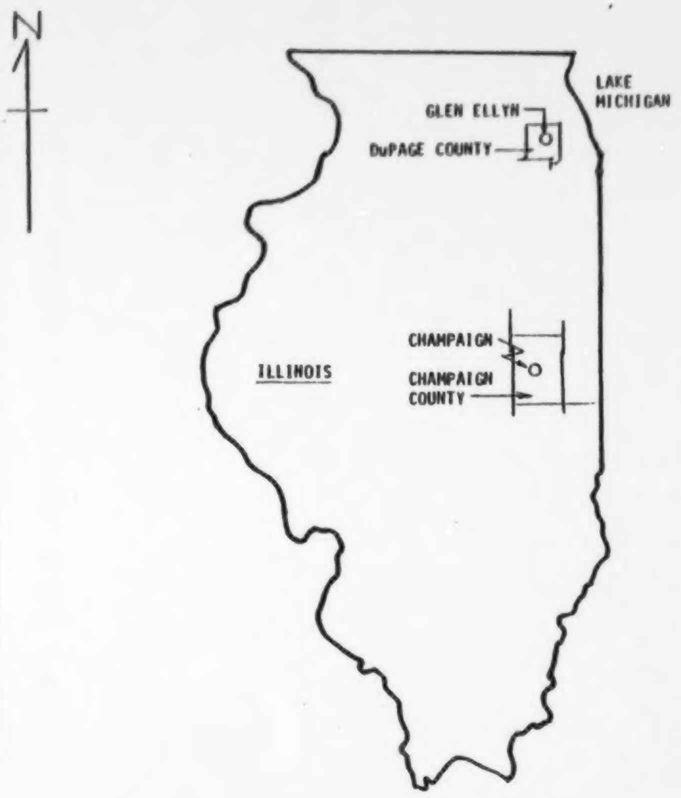
INTRODUCTION

This project is located in the community of Glen Ellyn, DuPage County, approximately 25 miles west of Chicago, Illinois. Area topography consists of gentle slopes, with drainage through Lake Ellyn into the East Branch of DuPage River.

The DuPage River, including the East Branch, is grouped in the category of Illinois rivers and streams designated for general use. The alternate category, to which certain named rivers and streams are assigned is designated for secondary contact and indigenous aquatic life waters.

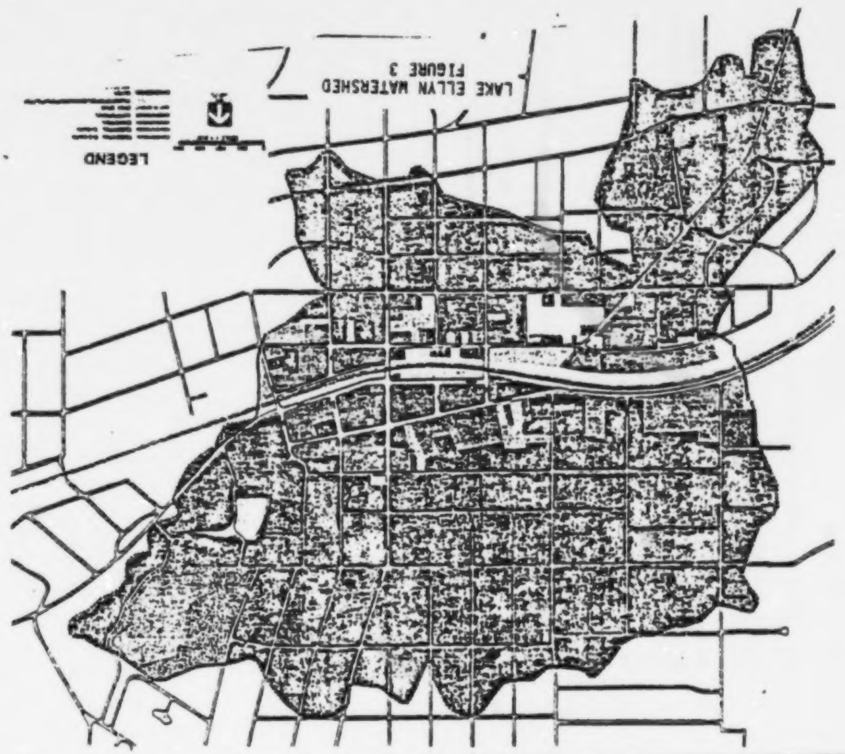
The East Branch of the DuPage River, into which Lake Ellyn discharges, receives wastewater treatment plant point source discharges at sixteen points. Maintenance dredging of Lake Ellyn has been accomplished to attempt to retain its use as a popular recreation area for boating, fishing (primarily for carp) and outdoor activities. Lakes in the system, including Lake Ellyn, are subject to rapid eutrophication unless routine maintenance dredging is performed, experiencing water quality problems in both the water column and sediments. The actual drainage area for Lake Ellyn is 534 acres, located in an area with a population of 5,000/mi^2, resulting in an approximate population of 4,200 in the watershed. DuPage County is extremely fast growing in population, and ranks close to the top nationwide in this respect.

This study will determine the accumulation and fate of pollutants from various sources, such as roof runoff, street surfaces, catchbasin/storm sewers, and Lake Ellyn, serving as a detention basin. These sources are being evaluated as control points along the flow path where control strategies may be effectively employed. Evaluation will be directed towards determining if controls can be applied to effectively alter lake conditions, or whether Lake Ellyn should be utilized as a detention basin, and provide for periodic maintenance dredging.



STATE LOCUS
ILLINOIS NURP PROJECTS

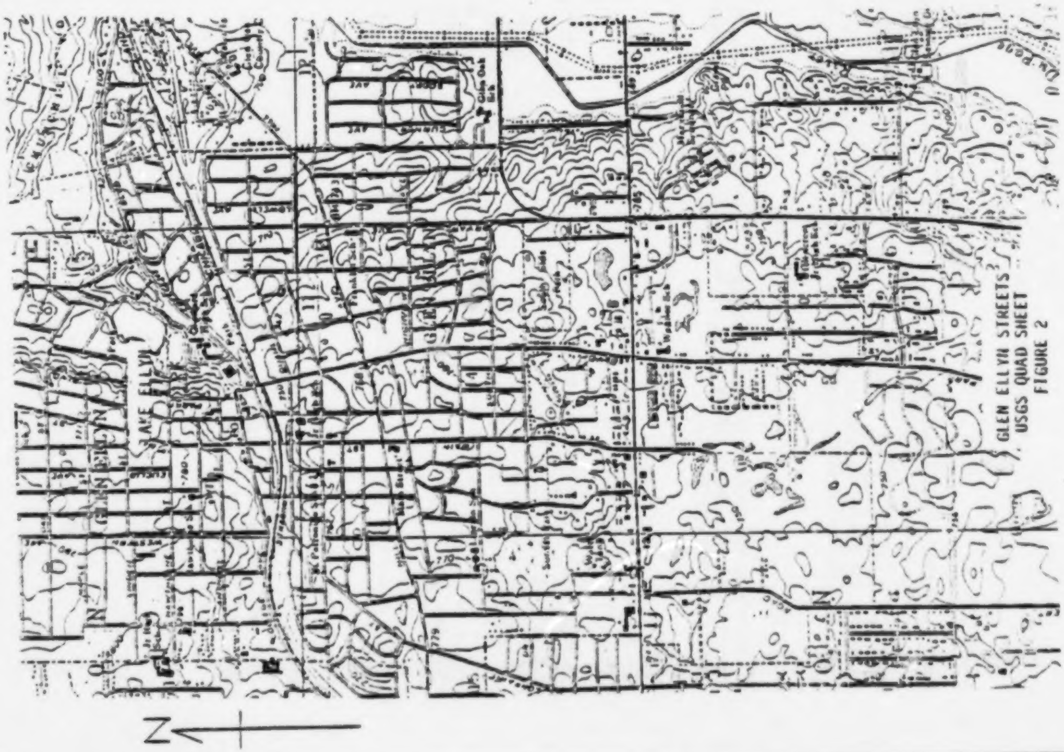
FIGURE 1



LAKE ELLYN WATERSHED
FIGURE 3

G17-5

Reproduced from best available copy.



GLEN ELLYN STREETS
USGS QUAD SHEET
FIGURE 2

G17-4

PHYSICAL DESCRIPTION

A. Area

The City of Glen Ellyn, situated in DuPage County, is located in northeastern Illinois, approximately 25 miles west of Chicago, which borders the southwestern end of Lake Michigan. The area of the Glen Ellyn watershed totals 534 acres, and the total area of Glen Ellyn is 4,096 acres. Land use is 80 percent low density residential, with the remaining 20 percent made up of high density residential, wetland, commercial, parkland, and institutional uses.

B. Population

The total city population is 23,649, with approximately 4,200 located within the Lake Ellyn watershed. DuPage County is included in the Chicago Standard Metropolitan Statistical Area.

C. Drainage

Glen Ellyn's topography consists of gentle slopes, with the watershed average 220 feet per mile.

The East Branch DuPage River originates in DuPage County. Glen Ellyn is in the headwater of a tributary, about 1/4 mile east of the East Branch. Drainage from most of Glen Ellyn is conveyed to Lake Ellyn, from which it flows through a feeder stream into the East Branch, DuPage River. The East and West Branches join to form the DuPage River which then flows into the DesPlaines River and then into the Kankakee and the Illinois Rivers, on the way to the Mississippi River. Artesian springs supplied by the St. Peters aquifer, which originally gave Glen Ellyn its reputation as a resort, are no longer productive due to the lowering of the aquifer by about 100 feet. A large part of the base flow in the East Branch DuPage River is now the effluent of several waste treatment facilities, and contains high bacteria levels.

D. Sewerage System

The existing watershed is served by an extensive network of paved streets with curbs and gutters and underground storm sewers. A separate sanitary system serves to convey the sanitary wastes to the wastewater treatment plant, with outfall to the East Branch DuPage River.

PROJECT AREA

I. Catchment Name - Lake Ellyn watershed

A. Area - 534 acres

B. Population - approximately 4,200

C. Drainage - Lake Ellyn drains through a 1/4 mile long tributary to the East Branch DuPage River, with a slope of 49 feet/mile.

D. Sewerage - Lake Ellyn watershed is 95% served by separate storm sewers; 98% of the streets have curb and gutter drainage, and 2% have ditch and swale drainage.

Street density is 21.6 miles/square mile.

E. Land Use

427 acres (80%) is 0.5 to 2 dwelling units per acre urban residential.

16 acres (3%) is 8 dwelling units per acre urban residential.

27 acres (5%) is central business district urban commercial.

10 acres (2%) is wetlands.

27 acres (5%) is urban parkland.

27 acres (5%) is urban institutional.

PROBLEM

A. Local definition (government)

The present water quality of Lake Ellyn is only capable of supporting carp, and has required periodic maintenance dredging to remove the accumulated polluted sediments. Due to its park setting and recreational uses the condition of the water in Lake Ellyn is of concern to the local populace; much less concern has been expressed about the East Branch DuPage River, where base flow is primarily sanitary effluent from several wastewater treatment plants, and major uses of this River are for flood control and waste transport.

B. Local Perception (Public awareness)

Due to the location of Lake Ellyn within the major recreational park of the City of Glen Ellyn, the public is aware of the condition of the water in the lake. From that point downstream, including the East Branch DuPage river there is little concern about the water quality issue.

PROJECT DESCRIPTION

A. Major objectives

Previous evaluations have stated that the watershed contributary to Lake Ellyn has so great an impact that a continuing maintenance program is essential to its survival as an attractive lake. This study is designed to assess the control potential of wet-bottom detention facilities, represented by Lake Ellyn, in removing pollutants from stormwater runoff, and identifying the pollutant sources and transport mechanisms.

Specific study objectives are:

1. Identify the originating sources of sediment, BOD, ammonia, nutrients, and metals and construct their respective material balances, (i.e., output = input ± storage ± transformations).
2. Quantify and qualify the effects of urban stormwater detention on water quality and, where possible, on bottom materials in the detention basin.
3. Identify the design factors necessary for siting, sizing, and operating storage facilities, based on the analysis of runoff variables such as magnitude and duration, pollutant settling characteristics and reoccurrence of flow and pollutant loads.
4. Evaluate the relative importance of wet and dry periods and seasonal variation in terms of pollutant load movement, bottom material characteristics and water quality.
5. Investigate the lag effect in the movement of sediments through the drainage system by determining the time delay between the input of the constituent to the drainage pathways and its output to Lake Ellyn.
6. Identify the measurable physical and anthropogenic characteristics of the watershed and attempt to relate these to urban runoff quantity and quality to determine whether these characteristics are sufficient to define water quality problems and design solutions.

The second year project report included the water year ending September 30, 1980. For the purpose of accomplishing the listed objectives, second year work tasks included atmospheric deposition sampling, source surveys, control point sampling, runoff water quality monitoring, and detention basin bottom material and water column sampling. The report is for the period April 1, 1980 through March 31, 1981.

B. Methodology

Atmospheric deposition sampling is providing information on the atmospheric input of pollutants by rain and dry fallout. To date forty-two weeks of wet, dry and bulk samples have been collected from two locations in the watershed by the Illinois State Water Survey.

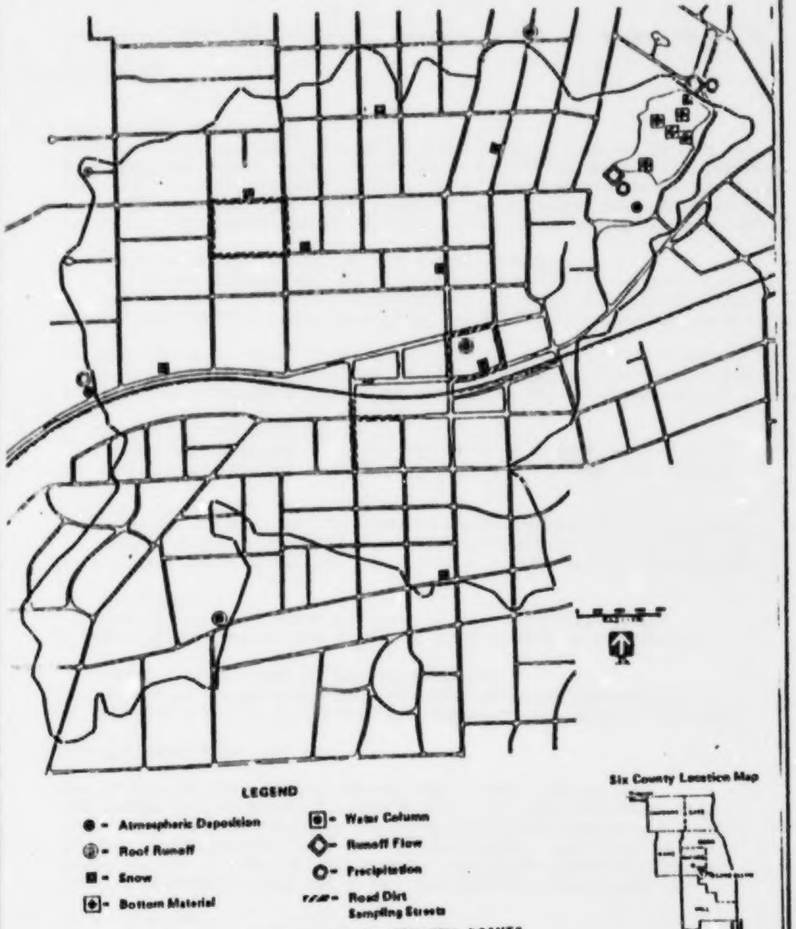
Field surveys have examined six sources of pollutants; soil, vegetation, animals, vehicular traffic, decomposition of impervious surfaces, and home and public works use of chemicals. Constituent concentrations in parkway soils have been determined for three traffic classifications and varying distances from the roadway. The quality of leachate from watershed soils has also been analyzed in the laboratory. Surficial geology information has been assembled from recent borings undertaken near Lake Ellyn.

Constituent concentrations in the predominant forms of vegetation in the watershed have been determined. The Illinois Department of Conservation undertook a fish survey of Lake Ellyn and a count of migratory birds was made at Lake Ellyn.

The results of the questionnaire prepared in the first project year have been tabulated. This has produced valuable information on home use of fertilizers and pesticides.

Estimates of peak and average daily traffic volume have been prepared and mapped. The quantity, type and condition of impervious surfaces in the watershed, including streets, driveways, parking lots and roofs, have been tabulated and mapped. In addition to these items, the environmental practices of the Glen Ellyn Public Works Department have been monitored. Data collected to date include street sweeping schedules, deicing application dates and quantitie and points of most frequent salt application.

The accumulation and fate of pollutants from the above sources also have been examined at four control points in the basin. These control points represent positions along the flow path from source to receiving water body where control strategies might be employed. The points are: rooftops; street surfaces; catch basin/storm sewers; and the detention basin. Samples of roof runoff for as many as six storm events have been collected and analyzed for roofs representing different pitch, vegetal influences and land use. An inventory of catch basin characteristics has been completed and samples from clean and dirty catch basins have been analyzed. Road dirt samples were collected during the spring and fall from sites representing different traffic and road surface conditions. Thirty snow samples also have been analyzed from snow lying in the gutters, on parkways and on lawns. The snow sample sites also represented various road conditions, traffic and land use. Five sets of three samples each of bottom material from Lake Ellyn have been analysed by the ISWS to determine the characteristics of material which has settled out of runoff to the lake. Sediment depths and current bottom topography for the detention basin have also been mapped. Three sets of detention basin water column quality data have been collected.



SAMPLING AND MONITORING POINTS
FIGURE 4

C. Monitoring

Sampling of runoff water quality, flow and precipitation began in March of 1980. Through September, 1980 nine storm events were monitored along with one low flow event and one snowmelt runoff event. Five minute flow data were gathered for all storms during the water year at the main inlet and both outlets. Five minute precipitation values were collected at two stations and fifteen-minute rainfall data were collected at a third.

Monitoring locations are identified in Figure 4. Water quality and flow data for inlet and outlet flows at Lake Ellyn are being obtained by the U.S. Geological Survey, using automatic monitoring equipment. Precipitation data is also being obtained at the same locations by the Survey.

Also indicated in Figure 4 are the locations of the other sampling efforts, including additional precipitation, atmospheric deposition, roof runoff, snow, lake bottom material, water column and street dirt.

The list of parameters and constituents examined in the samples collected includes: Sodium, Magnesium, Potassium, Calcium, Ammonia, Nitrate, Chlorides, Sulphate, Zinc, Iron, Copper, Cadmium, Lead, Chromium, Phosphate, Mercury, total suspended solids, total dissolved solids, chemical oxygen demand, 5 day biochemical oxygen demand, specific conductance, sediment oxygen demand, chlorophyll a, cell count, algal species, temperature, dissolved oxygen, organic nitrogen (total and dissolved) calcium carbonate alkalinity, hardness.

Equipment

The sites monitored by the Geological Survey have automatic sampling and flow recording samplers. Wetfall and dryfall sampling is also done by automatically controlled sampling equipment. Street dirt samples were obtained by use of an appropriate portable wet/dry vacuum. Lake Ellyn water samples were composited automatically, as determined necessary by the automatic flow recording devices.

Control

In addition to evaluating Lake Ellyn as a wet detention basin, other control measures will be considered that would affect the source and transport mechanisms disclosed during the investigation, which lend themselves to improvements that are cost-effective.

NATIONWIDE URBAN RUNOFF PROGRAM

WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

MADISON, WI

REGION V, EPA

INTRODUCTION

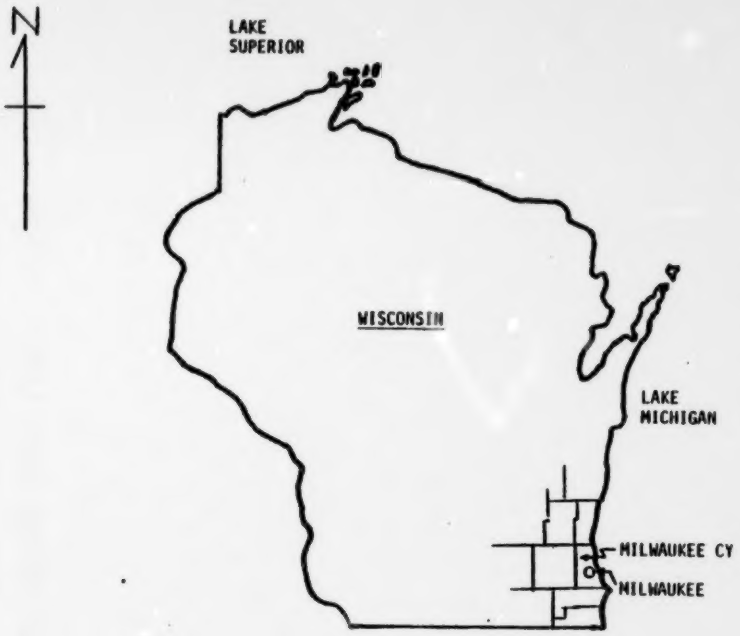
The City of Milwaukee, situated in Milwaukee County, is located in southeastern Wisconsin on the western shore of Lake Michigan. The topography consists of gentle rolling hills drained by tributaries to, and the Menomonee, Milwaukee and Kinnickinnic Rivers, which flow into Milwaukee Bay in Lake Michigan. Other shoreline drainage enters the lake directly.

The Menomonee River is used for hydropower production, waste assimilation, and industrial water supply. Fishing, recreation, aesthestic values and stock and wildlife watering are common. Water quality requirements and standards shall meet the standards for recreational use and fish and aquatic life. Lake Michigan waters shall meet the standards for public water supplies and the standards for recreational use and fish and aquatic life. The intrastate rivers also are classified to meet these same standards, although not identified by name. Previous studies have shown that surface waters are severely polluted, and a large proportion can be attributed to urban pollution.

This city has had a decline in population during the last 10 years. The census of populations for the city, the urbanized area and the standard metropolitan statistical area have been recorded for 1970 and 1980; they show a population declining faster in the city than in the urbanized area or the SMSA. The recorded census population for the city in 1980 was 636,200, which represented an 11.3% decline from 717,100 in 1960. The 1980 urbanized area population declined 3.6%, and the SMSA declined 0.5% during the same period.

As these changes indicate, the increasing population of the past within the urban and standard metropolitan statistical areas changed to a decreasing population during the last 10 years. The city population had started decreaseing during the 10 year period beginning in 1960. Its quite likely that much of the initial city population decline represented relocation away from the urbanized area into the urbanizing areas of the SMSA. This is the only project area in Region V to show a decline in population trend.

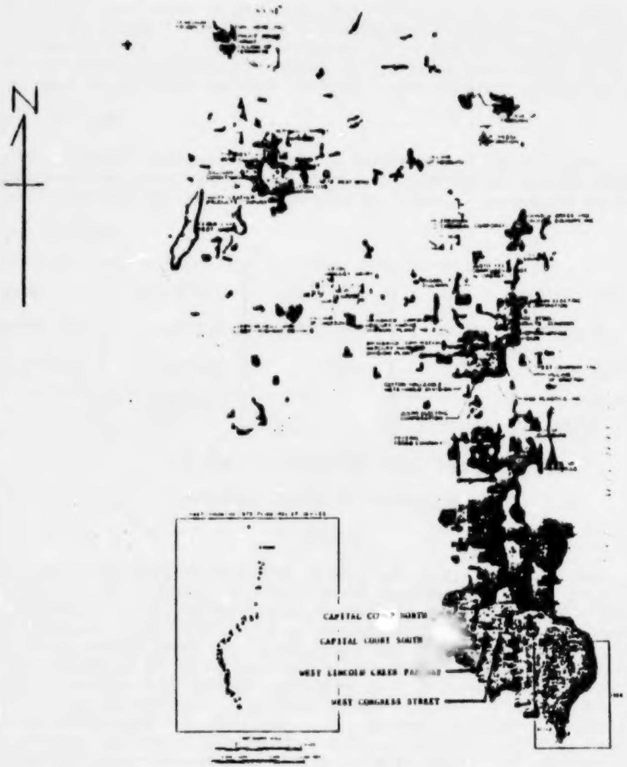
Previous evaluation of the water quality of the local drainage system identified urban stormwater runoff as a major concern. As a result, the Areawide Water Quality Management Plan for Southeastern Wisconsin has recommended reduction of pollutants from urban runoff through implementation of appropriate practices and control measures. This project is designed to evaluate the effectiveness of alternative streetsweeping schedules in varying land use conditions.



STATE LOCUS

WISCONSIN NURP PROJECT

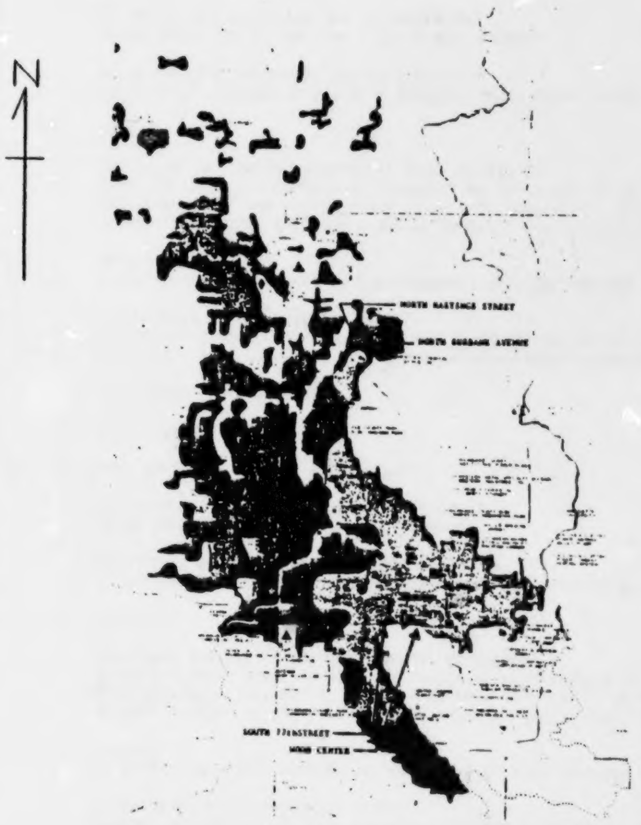
FIGURE 1



NURP STUDY SITES IN THE

MILWAUKEE RIVER WATERSHED

FIGURE 2



NURP STUDY SITES IN THE

MENOMONEE RIER WATERSHED

FIGURE 3

PHYSICAL DESCRIPTION

A. Area

The City of Milwaukee, situated in Milwaukee County, is located on the western shore of Lake Michigan, in southeastern Wisconsin. The total area of city comprises about 95 square miles of land. Land use within the city is characterized as institutional, residential, commercial and industrial.

B. Population

As noted in the introduction, and in Table 1, below, city population has declined from about 741,500 in 1960 to about 636,200 in 1980. During ths same period the urbanized area and SMSA show a net increase, although over the last ten years both show declines. If these trends continue, projected year 2000 population could be down another 100,000 or more to around 510,000. It is much more reasonable to expect the rate of decline to be damped and the city population to not drop much lower than 600,000 over the next twenty years. This is based on the assumption that a lot of the decline represented movement out of the urban areas to the urbanizing suburbs, as percentage changes for those areas seem to indicate. A reverse trend already seems to be starting in metropolitan areas which will balance in part the initial move outward.

TABLE I

DECENNIAL CENSUS OF POPULATIONS

MILWAUKEE, URBANIZED AREA, SMSA

	1960 (APPROX)	1970	% Change	1980	% Change
Milwaukee	741,570	717,099	-3.3	636,212	-11.3
Urban Area	1,150,100	1,252,457	+8.9	1,207,008	- 3.6
SMSA	11,278,400	1,403,688	+9.8	1,397,143	- 0.5

C. Drainage

The gently rolling terrain of the City of Milwaukee is drained by the Milwaukee, Menomonee and Kinnickinnic Rivers and their tributaries into Milwaukee Bay in Lake Michigan. Shoreline drainage is directly into Lake Michigan.

D. Sewerage

The City of Milwaukee sanitary sewerage system consists of both public and private sewage treatment facilities, and combined sewer outfalls, by passes, crossovers and relief pumping stations. This type of system produces point source pollution at the various discharge points throughout the system whenever excessive flows occur or hydraulic characteristics prove inadequate.

PROJECT AREA

I. Catchment Name WI 1, 630, State Fair

A. Area - 29 acres.

B. Population - 290 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 2.9 lane miles of asphalt, 31% of which is in good condition, and 69% of which is in poor condition. In addition, there are about 0.6 lane miles of concrete, of which 83% is in good condition and 17% of which is in poor condition.

E. Land Use

7.54 acres (26%) is 2.5 to 8 dwelling units per acre urban residential, of which 5.9 acres (78.2%) is impervious.

21.46 acres (74%) is Linear Development, of which 16.4 acres (76.4%) is impervious.

II. Catchment Name - WI 1, 631, WOOD CENTER

A. Area - 44.9 acres.

B. Population - 540 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 4.2 lane miles of asphalt, 14% of which is in good condition, and 86% of which is in poor condition. In addition there is about 1 lane mile of concrete, of which 80% is in good condition and 20% of which is in poor condition.

E. Land Use

13.84 acres (30.8%) is 2.5 to 8 dwelling units per acre urban residential, of which 11.22 acres (81.1%) is impervious.

25.28 acres (56.3%) is Linear Strip Development, of which 20.5 acres (81.1%) is impervious.

5.6 acres (12.5%) is Urban Industrial (heavy), of which 4.54 acres (81.1%) is impervious.

III. Catchment Name - WI 1, 632, N. Hastings

A. Area - 32.84 acres.

B. Population - 560 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 2.2 lane miles of concrete, all of which is in good condition.

E. Land Use

32.84 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 16.86 acres (51.3%) is impervious.

IV. Catchment Name - WI 1, 633, N. Burbank

A. Area - 62.6 acres.

B. Population - 915 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Street consist of 4.1 lane miles of concrete, 97% of which is in good condition, and 3% of which is in poor condition.

E. Land Use

62.6 acres (100%) is 2.5 to 8 dwelling units per acre urban residential, of which 31.27 acres (50%) is impervious.

V. Catchment Name - WI 1, 634, Rustler

A. Area - 12.44 acres.

B. Population - 0 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 0.6 lane miles of asphalt, 100% of which is in good condition.

E. Land Use

12.44 acres (100%) is Shopping Center, of which 12.39 acres (99.6%) is impervious.

VI. Catchment Name - WI 1, 635, Post Office

A. Area - 12.08 acres.

B. Population - 0 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

E. Land Use

12.39 acres (100%) is Shopping Center, of which 12.12 acres (97.8%) is impervious.

VII. Catchment Name - WI 1, 636, Lincoln Creek

A. Area - 36.1 acres.

B. Population - 650 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 0.1 lane miles of asphalt, 100% of which is in poor condition. In addition there are about 4.4 lane miles of concrete, of which 62% is in good condition and 38% of which is in poor condition.

E. Land Use

34.91 acres (96.7%) is 2.5 to 8 dwelling units per acres urban residential, of which 20.0 acres (5.73%) is impervious.

1.11 acres (2.5%) is Linear Strip Development, of which 0.64 acres (57.7%) is impervious.

VIII. Catchment Name - WI 1, 637, W. Congress

A. Area - 33.04 acres.

B. Population - 540 persons.

C. Drainage - This catchment area has a representative slope of 160 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 160 feet/mile slope.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 100 lane miles of concrete, 54% of which is in good condition and 46% of which is in poor condition.

E. Land Use

30.1 acres (91.1%) is 2.5 to 8 dwelling units per acre urban residential, of which 15.19 acres (50.5%) is impervious.

2.32 acres (7.0%) is Linear Strip Development, of which 1.17 acres (50.4%) is impervious.

PROBLEM

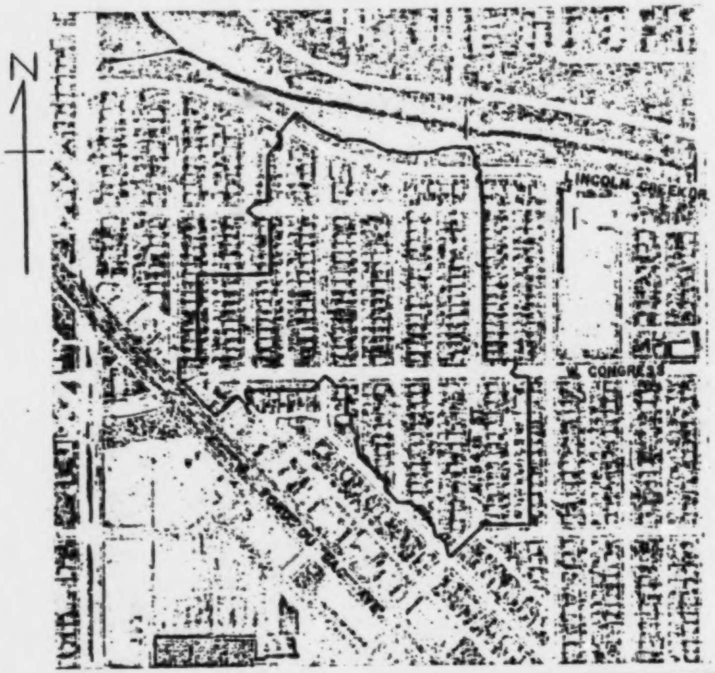
A. Local Definition (Government)

Considerable effort has been expended on the assessment of urban stormwater problems in Milwaukee County. The assessments have been made for the Milwaukee, Kinnikinnic and Menomonee River Watersheds. Most of the study areas for the proposed project are in the Menomonee River Watershed. A large amount of water quality data was collected for the evaluation of urban pollution in the Menomonee River Watershed. The sources of water quality data include: The SEWRPC-DNR 1968-1974 continuing water quality monitoring program, a 1968-1969 watershed-wide phosphorus study, three 24-hour synoptic surveys conducted under the Menomonee River Watershed planning program and the Menomonee River Pilot Watershed Study. An examination of the water quality data from previous studies reveals the surface waters are severely polluted. The categories of pollutants included are toxic, organic, nutrient, pathogenic, sediment and aesthetic. The specific pollutants are lead, BOD, phosphorus, fecal coliform and suspended solids. The results of the Menomonee River Pilot Watershed Study revealed a significant portion of these pollutants transported in the stream can be attributed to urban runoff. The concentration of these pollutants are above stream quality standards during runoff events. Over 60 percent of the annual loading of phosphorus, lead and suspended solids is from nonpoint sources. The Southeastern Wisconsin Areawide Water Quality Management Planning Program is recommending nonpoint source control of the above pollutants in the proposed study areas. The practical consequence of these polluted conditions is to severely restrict the use of the watershed stream system for recreational pursuits and propagation of fish and aquatic life.

Literature values of the effectiveness of street sweeping are variable and are specific to locality of the study. Recent evaluation of improved street sweeping practices have observed up to 50 percent reduction in the amounts of phosphorus, lead and suspended solids coming from urban watersheds. A street sweeping study using two small watersheds in Minneapolis-St. Paul observed a reduction of 50 percent in phosphorus loading for the watershed with higher sweeping frequencies. A similar comparison between watersheds in Sweden produced reduction in suspended solids concentrations of 57 percent and 30 to 60 percent in lead concentration. A study in San Jose, California evaluating reduction of street surface loading by street sweeping observed between 13 and 60 percent of the street solids loading was removed. If street sweeping is shown to reduce the urban nonpoint source pollutant loading by as much as 50 percent in the SEWRPC area, street sweeping could be an important part for realizing a 25 percent reduction in urban nonpoint source pollution.

B. Local Perception (Public Awareness)

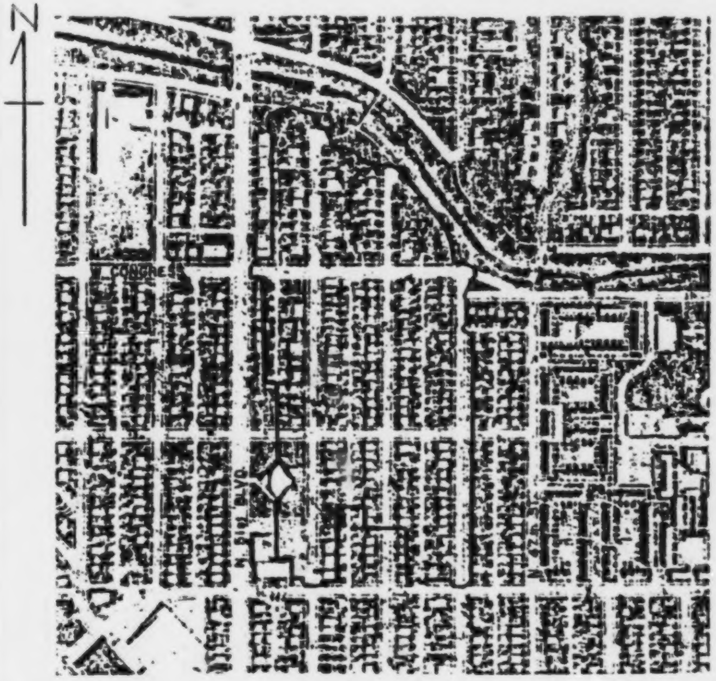
The limitations placed on the use of the watershed stream system for recreational pursuits has assured that members of the general public with an interest in that direction are aware of the problem. Community interest has resulted in the preparation of comprehensive watershed plans for both the Menomonee and the Milwaukee River watersheds.



Reproduced from
best available copy.

WEST LINCOLN CREEK PARKWAY
STUDY SITE
(PAIRED WITH W. CONGRESS ST. STUDY SITE)

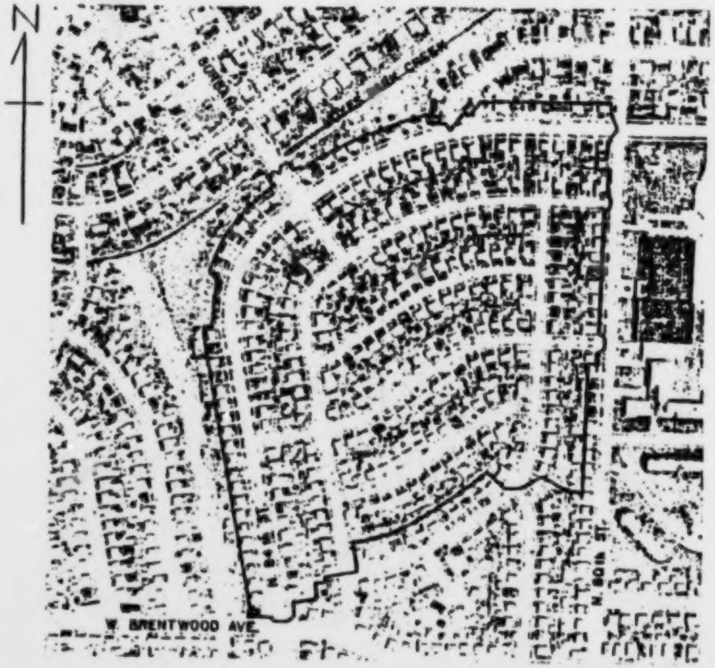
FIGURE 4



WEST CONGRESS STREET STUDY SITE
(PAIRED WITH W. LINCOLN CREEK PARKWAY STUDY SITE)

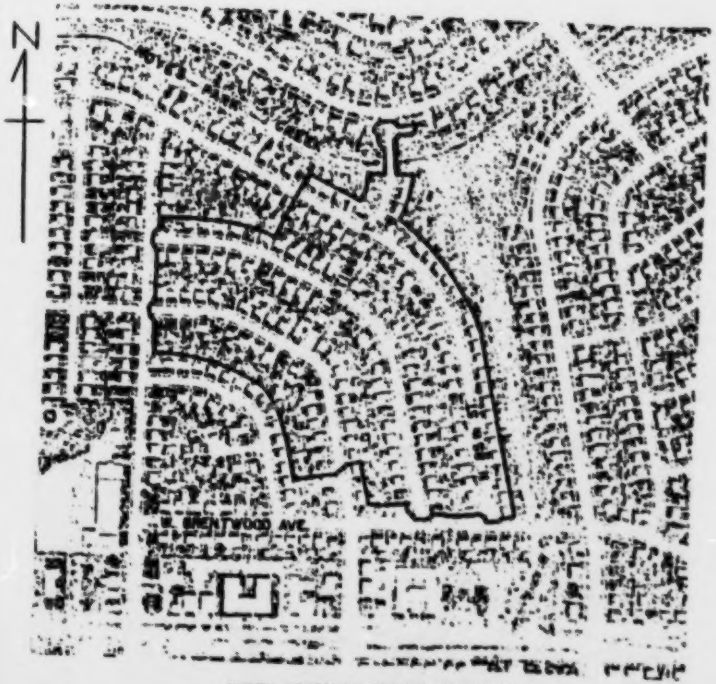
FIGURE 5

Reproduced from
best available copy.



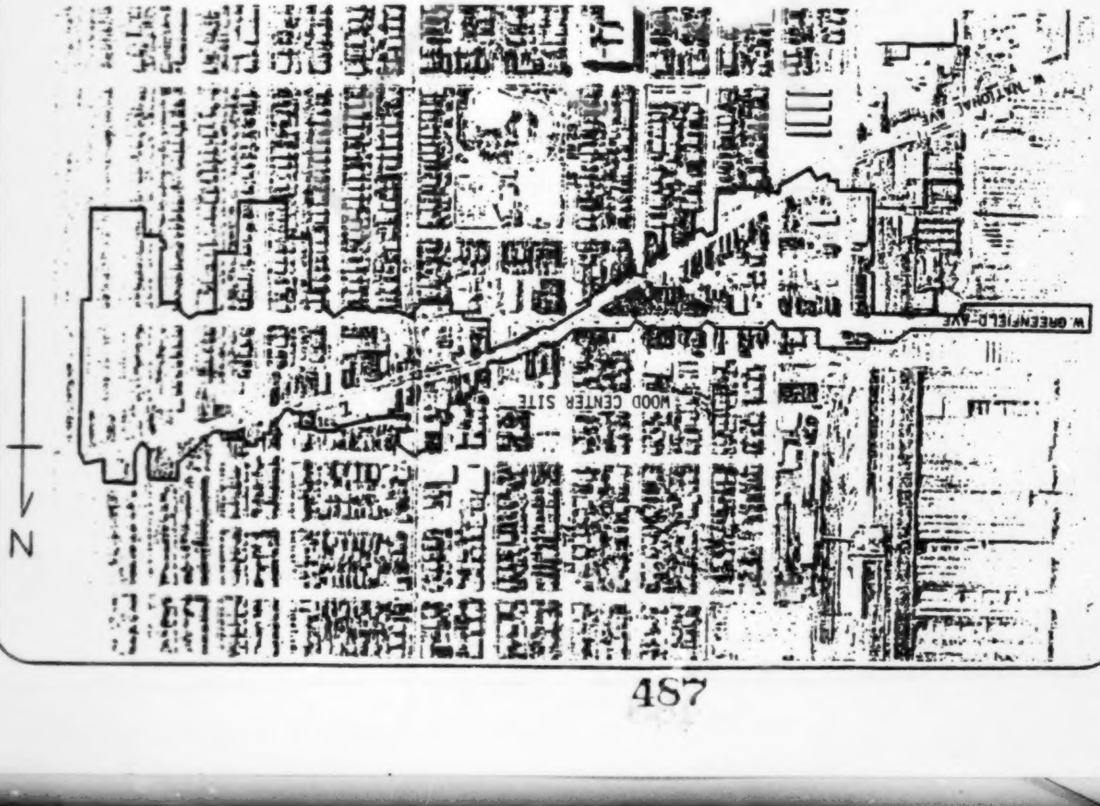
NORTH BURBANK STREET STUDY SITE

FIGURE 6



NORTH HASTINGS STREET STUDY SITE

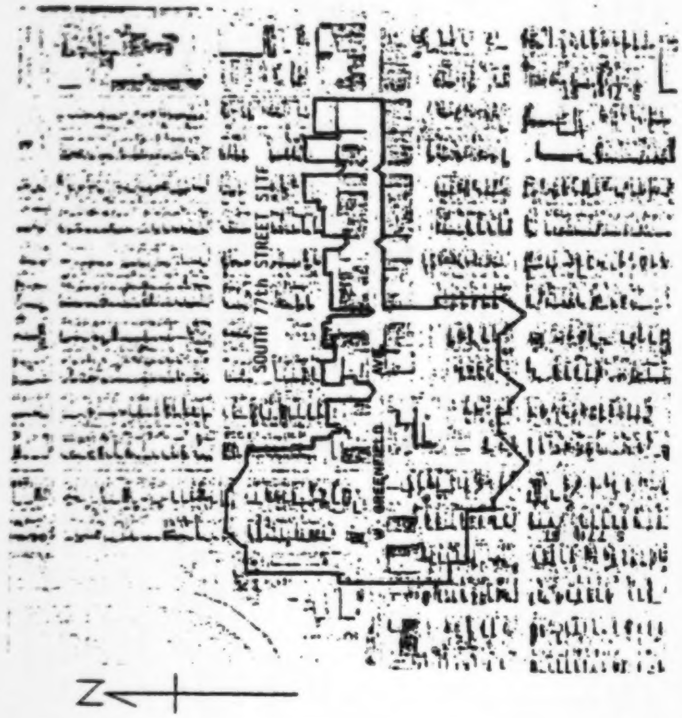
FIGURE 7



WOOD CENTER STUDY SITE

(PAIRED WITH SOUTH 77th STREET STUDY SITE)

FIGURE 8

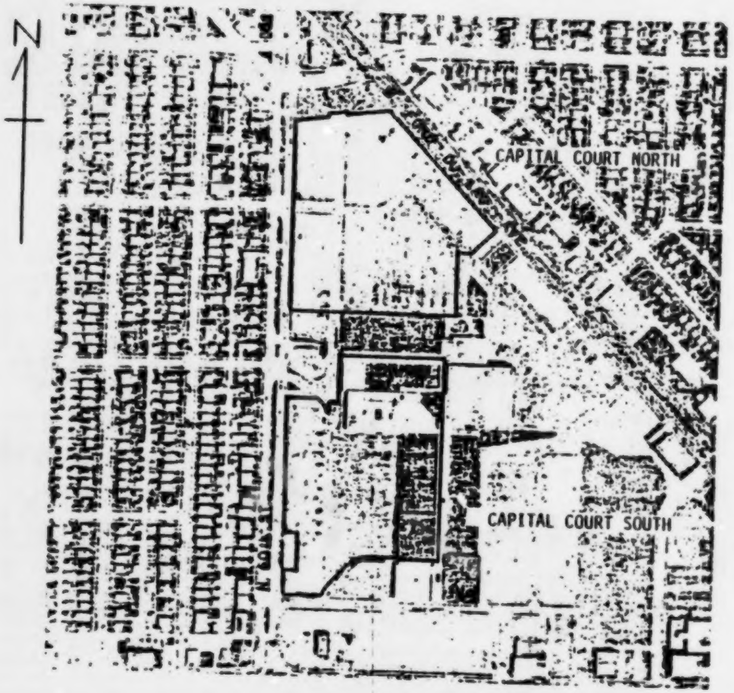


Reproduced from best available copy.

SOUTH 77th STREET STUDY SITE

(PAIRED WITH WOOD CENTER STUDY SITE)

FIGURE 9



CAPITAL COURT NORTH
AND
CAPITAL COURT SOUTH
PAIRED STUDY SITES

FIGURE 10

PROJECT DESCRIPTION

A. Major Objective

The Areawide Water Quality Management Plan for Southeastern Wisconsin contains the recommendation that a 25 percent reduction in urban nonpoint source pollution be achieved for 84 percent of the urban area within the region. The recommendation for the remaining 16 percent of the area is a 50 percent reduction through implementation of appropriate practices.

Among practices that may be implemented to achieve the 25% reduction is street sweeping. The need to know the effectiveness of improved street-sweeping programs in the region will become critical if regulatory mechanisms for urban nonpoint source controls are to be considered seriously. At the time this project was developed, the percent reduction in urban nonpoint source pollution reduced by improved street sweeping programs was unknown for the Southeast Wisconsin Regional Planning Commission area.

One of the objectives of this project is to evaluate the effectiveness of the timing and frequency of street sweeping in Milwaukee County. A second objective is to develop a methodology usable by municipalities to design urban nonpoint source control programs to meet water quality objectives. In addition, this project will evaluate the contribution of pollutants from rooftops, atmospheric dry and wet deposition, and winter accumulation to urban watersheds.

B. Methodologies

Street sweeping as a practice has most often been used for the aesthetic improvements resulting, and in coordination with stormdrain catchbasins cleaning programs to prolong the time between required cleanings.

The primary purpose of this project is to evaluate the potential improvement in stormwater quality caused by an accelerated street sweeping program. To evaluate this management technique, a test and control study design was selected. To assess the impacts of street sweeping on various land uses, pairs of small, homogeneous watersheds were selected for study. The selected land uses include pairs of medium density residential, high density residential, commercial strip and parking lot areas. One of the watersheds of each pair was designated the test area, and the other the control area.

Each control area is regularly swept using the same baseline frequency at which it has customarily been swept. For the residential control areas the baseline frequency is once per month, for the commercial strip control area it is once per week, and for the parking lot control area it is every two months.

Conversely the test areas have alternating sweeping frequencies. For some periods, the sweeping frequencies in the test areas are identical to the sweeping frequencies in the corresponding control areas. These periods are called control periods. At other times the sweeping frequencies in the test areas are higher than in the control areas. These are called test periods. The accelerated sweeping frequencies were selected to represent the possible range of sweeping frequencies that might be socially and economically acceptable.

The increased frequencies in the residential areas are once and twice per week, in the commerical area they are twice and three times per week, and in the parking lot they are biweekly and weekly. The street sweeping schedule for 1980, 1981 and 1982 is given in Table 2.

During control periods, when the street sweeping frequencies in both the test and control watersheds are identical, the individual event and seasonal stormwater pollutant load will be compared to determine intrinsic pollutant loading differences between the areas. During test periods, the differences between the test and control area's seasonal pollutant load, after adjusting for intrinsic differences found during control periods, will be deemed attributable to the increased street sweeping. Test and control periods and test and control watersheds are necessary to calculate the theoretical pollutant load that a test area would have had during a test period, had it been swept at the control frequency.

Some simple hypothetical numbers will help illustrate the study design. If during a control period a control area discharges 100 kg of suspended solids, and the corresponding test area discharges 120 kg, the test area intrinsically discharges 20% more suspended solids than the control area. If in the next test period, with perhaps less rainfall, the control area discharges 80 kg of suspended solids, the theoretical test area pollutant load, under normal street sweeping frequency, would have been 96 kg. If instead the observed test area suspended solids load was 67 kg, the difference due to street sweeping would be considered 29 kg, or 30% of the potential suspended solids load.

The length of the test and control periods are each approximately eight weeks long. By long term averages there are 12 to 16 events of greater than 0.1 inch precipitation per eight week period. There are three test periods per annual street sweeping season (spring, summer and fall), separated by two control periods.

Ideally there should be 12 to 16 sampled events per period from which to derive seasonal pollutant loads. Seasonal loading differences are desired for comparison because they will be more representative of the overall effect of an accelerated street sweeping program than will be individual differences observed from singular events.

Composite sampling is being used to monitor stormwater quality. Composite sampling allows for excellent analysis of monitored events, but because of the relatively small number of events per sampling period, there is not likely to be enough analyses to make statistically good pollutant loading estimates of unmonitored events. Initially only those events, wherein the samplers at both the test and control areas functioned properly, were to be included in the seasonal loading comparison of each pair. However, there has been a much higher incidence of sampler failure than had been anticipated. Within each pair of sites, there has been more events wherein a sampler at either one or both the test and control sites failed, than there has been when both samplers operated properly. Consequently, by the above criterion, most events would not be included in the seasonal loading comparison.

TABLE 2

STREET SWEEPING SCHEDULE

INCLUSIVE DATES	PERIOD	SWEEPING FREQUENCY (TIMES/MONTHS)					
		Residential		Commercial		Parking Lots	
		Test Areas	Control Areas	Test Area	Control Area	Test Area	Control Area
5/18/80-7/5/80	CONTROL	1	1	4	4	.5	.5
7/6/80-8/23/80	TEST	4	1	12	4	4	.5
8/24/80-10/11/80	CONTROL	1	1	4	4	.5	.5
10/12/80-11/29/80	TEST	4	1	12	4	4	.5
3/15/81-5/2/81	TEST	8	1	8	4	2	.5
5/3/81-6/20/81	CONTROL	1	1	1	4	.5	.5
6/21/81-8/15/81	TEST	8	1	8	4	2	.5
8/16/81-10/3/81	CONTROL	1	1	1	4	.5	.5
10/4/81-11/28/81	TEST	8	1	8	4	2	.5
3/7/82-4/17/82	TEST	4	1	12	4	4	.5
4/18/82-5/22/82	CONTROL	1	1	4	4	.5	.5
5/23/82-7/3/82	TEST	4	1	12	4	4	.5

One analytical alternative is to compare seasonal flow weighted average concentration for all monitored events at each station. This would allow for the inclusion of many more events in the seasonal comparison. On the other hand, different events at the test and control sites would be included in the overall analyses, which raises different concerns. Hopefully, the incidence of sample failure will be reduced as some of the initial sampling problems are resolved.

In addition to the water quality monitoring, further analyses of street sweeping will be based on the monitoring and analysis of contaminants on the street surfaces of the test areas. Street surface contaminants will be collected in a manner as to analyze for three functions: the accumulation of materials on streets over time, street sweeper removal efficiencies and rainfall-washoff processes. This information will be useful for modeling purposes, in order to extrapolate to various street sweeping frequencies and rainfall regimes.

A private street cleaning contractor is sweeping all of the study areas. A private contractor was chosen to do the sweeping, rather than the respective municipalities, in order to maximize our control over, and consistency within, the street sweeping operation, and to facilitate coordination and communication with the operators.

A contractor uses a 1969 four wheel, rear end brush, Mobil street sweeper. The sweeper operates at five miles per hour, spraying dust suppressing water on the street as it travels. The strike of the broom is maintained at six inches. There is one principal operator of the sweeper, with an occasional stand-in operator. The principal operator has had more than 30 years of street sweeping experience with the City of Milwaukee.

The streets are being swept in accordance with the schedule given in Table 4. The control areas are swept at their usual and customary sweeping frequency. The sweeping in the test areas alternates between the control frequencies and accelerated frequencies. The alleys in the study areas are considered another pollutant source as are rooftops, sidewalks and driveways. These alleys are normally swept three to four times per year. We are maintaining the normal sweeping frequency in the alleys of both test and control study areas.

The usual leaf pick-up program in Milwaukee and West Allis is to, on designated dates at preselected intervals, ask the residents to rake all of their leaves into the gutters. Jeeps equipped with leaf rakes then push the leaves to the corners of the blocks, where Vac-Alls or front end loaders and dump trucks pick up the leaves. Our street cleaning contractor does not have the equipment to handle a large leaf pick-up program. Nor are there funds to contract the leaf pick-up to another party. Therefore the municipalities will maintain their usual leaf pick-up program in the study areas.

Stormwater pollutant loads are determined through the use of composite sampling techniques. The decision to use composite rather than stratified random sampling followed an analysis of the latter, which indicated that, based upon available urban stormwater concentrations, as many as 100 samples per station per test period could be required to achieve a ± 20% error term on the pollutant loading estimate. By contrast, as few as 12 to 16 composite analyses will be required to get a good seasonal loading estimate, but the resultant loading estimates will not have associated error terms. A report of this analysis, with a description and comparison of integration, composite and stratified random sampling, is being reviewed prior to publishing by the Wisconsin Department of Natural Resources.

The sampling stations are equipped with Manning S-4050 samplers. Samples are collected flow proportionally during events. Either one, one liter or two, half liter samples are placed in each sample bottle. The samples are refrigerated to 4°C. When the event has ended, the samples are removed from the stations and transported on ice to the Department of Natural Resources Southeast District Headquarters in Milwaukee for processing.

At the district lab the samples are split using a USGS cone splitter and recombined to get a single one to two liter flow weighted composite sample. Each composite is then further split into five separate samples for filtering and/or fixing as needed for the various parameters. The samples are then transported to Madison on ice and refrigerated at the State Lab of Hygiene until analyzed. The State Lab is performing all of the sample analyses. A listing of water quality parameters is given in Table 3.

In addition to the composite sampling, for five events per station per year when more than ten sample bottles have been filled, discreet analyses will be done on six of the samples per event. To do so, one-tenth of each sample (0.1 liters) will be split off and combined to get a single composite sample. The remaining nine-tenths (0.9 liters) of each of the six discreet samples will then be analyzed separately.

Finally, on large events, the suspended sediment will be separated from the collected samples, divided into particle sizes, and analyzed for contaminants. Analysis of particle sizes will occur whenever 14 or more sample bottles have been filled. After a one to two liter composite sample is split off of the total sample volume, the remaining sample (twelve or more liters) is sent to the USGS Hydraulics Lab for analysis.

C. Monitoring

The project provides for monitoring four pairs of study sites, each pair consisting of a control site and an experimental site. The pairs were selected to be of matched and uniform land use types, in close proximity to each other. Figures 2 and 3 depict the locations of these paired sites, and Figures 4 through 10 provide street layouts of the individual or paired sites.

Table 3 includes general characteristics of the study sites, including the primary land use designations.

TABLE 3

GENERAL CHARACTERISTICS OF STUDY SITES
NATIONWIDE URBAN RUNOFF PROGRAM
MILWAUKEE COUNTY, WISCONSIN

Study Site	Major Civil Divisions	Area (Acres)	Primary Land Use
W. Lincoln Creek Parkway	City of Milwaukee	37	High Density Residential
W. Congress Street	City of Milwaukee	33	High Density Residential
N. Burbank Avenue	City of Milwaukee	71	Medium Density Residential
N. Hastings Street	City of Milwaukee	43	Medium Density Residential
Wood Center	City of West Allis	45	Commercial/High Density Residential
S. 77th Street	City of West Allis	30	Commercial/High Density Residential
Capital Court North	City of Milwaukee	13	Commercial/ Parking Lot
Capital Court South	City of Milwaukee	12	Commercial/ Parking Lot

The stormwater quality constituents and parameters scheduled, and their frequency, are indicated in Table 4.

TABLE 4

STORMWATER QUALITY PARAMETERS

Frequency of Analysis	Parameters
Every event, all stations	Primaries*
	Total Solids Suspended Solids Volatile Suspended Solids Total Phosphorus Soluable Phosphorus Total Lead Chlorides
Every event during 1980, all stations	Secondaries
	Nitrate + Nitrite Ammonia Kjeldahl Nitrogen Soluble Lead
Every other event, all stations	Chemical Oxygen Demand
Every other event, all stations	Biological Oxygen Demand, Five Day
Every fourth event, all stations	Biological Oxygen Demand, Thirty Day
Every other event during 1980, test sites only	Multi-element Scan
One grab sample per event, all stations	Fecal Coliform
One grab sample per event, all stations	Fecal Streptococcus
Whenever 14 or more sample bottles have been collected, all stations	Particle Size
	Total Phosphorus Available Phosphorus Total Lead

*All samples are composite samples except for the fecals.

Equipment

Wisconsin Department of Natural Resources has provided automatic water quality sampling devices to the U.S. Geological Survey, and USGS has provided the automatic flow meters. Rainfall is also determined with automatic equipment. An automatic rainfall sensor initiates startup of the automatic recorders, and the automatic flow meters, which in turn activate the automatic samplers. In addition to the volumetric rainfall gage, there are automatic atmospheric wet fall/dry fall samplers.

Street surface sampling is accomplished in one of the paired sites (4 of 8, total), using a 1/2 ton van towing a trailer-mounted generator connected to two vacuum cleaners. The vacuums operate in tandum through a vacuum hose, wand and nozzle.

Water quality sampling was accomplished by composite sampling except during winter, when discrete sampling at 5 minute intervals was initiated.

Quality and flow monitoring is being accomplished by USGS, and streetsweeping sampling is being done by Southeast Wisconsin Regional Planning Commisssion.

Controls

This project is evaluating the effectiveness of streetsweeping as a practice for controlling pollution from urban stormwater runoff. Various land uses are being tested for different streetsweeping frequencies. Transferrability of results will be evaluated by modelling.

NATIONWIDE URBAN RUNOFF PROGRAM

TEXAS DEPARTMENT OF WATER RESOURCES AND
CITY OF AUSTIN, TEXAS

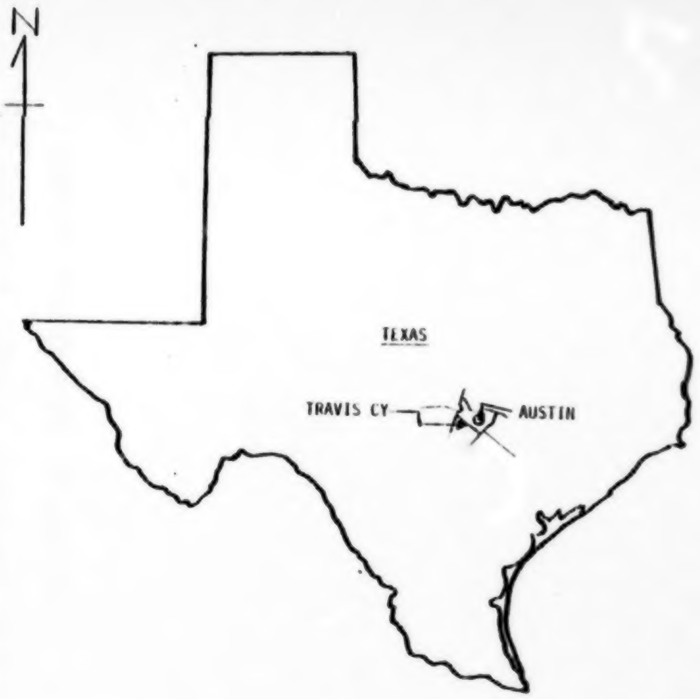
REGION VI, EPA

INTRODUCTION

The City of Austin, located in Travis County, lies along the Colorado River, in the central part of the State of Texas. The Colorado River empties into Matagorda Bay approximately 175 miles to the Southeast. The topography consists of gentle rolling hills, and the urban area is drained by streams flowing into the Colorado River.

The Colorado River, in the vicinity of Austin, is comprised of run of the river impoundments named Town Lake, Lake Austin and Lake Travis. Currently, Lake Austin serves as the primary drinking water supply for the city, with the original source, Town Lake, used as a supplemental source. Increasing urban density is encountered downstream from Lake Travis toward Town Lake. Urban stormwater runoff into Town Lake results in highly visible evidence of aesthetic degradation, and water from this source is not utilized for water supply during times. While this decision may be the result of the increased costs for treatment, rather than because of the concentration of pollutants, this study will clarify this. Water quality standards for all three lakes have been established as adequate to support contact and noncontact recreation, propagation of fish and wildlife, and for use as domestic raw water supply.

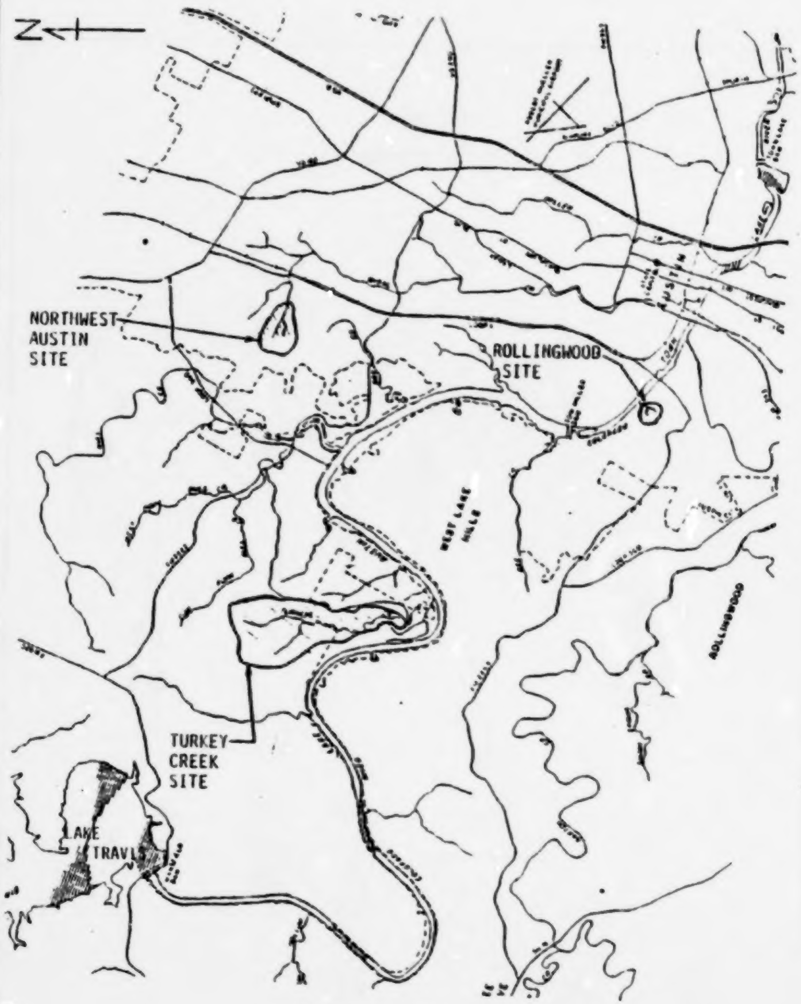
A major concern is to control urbanization in the Lake Austin area to prevent urban stormwater runoff problems similar to those experienced in Town Lake. The population of the Austin standerd metropolitan statistical area in 1950 was 162,336; this increased to 295,516 in 1970, an increase of 82% in 20 years. By 1980, the SMSA population was 536,450, a 10 year change of 81.2%. The city population, itself, went from 186,524 in 1960 to 251,808 in 1970, an increase of 35%. In the next decade it further increased to 345,496, or an increase of 37.2%. Much of the increase is occurring in the Lake Austin watershed. The 1960 urbanized area increased from 264,499 in 1970 to 379,322 in 1980, a jump of 43.4%, following a 41.3% increase between 1960 and 1970.



STATE LOCUS

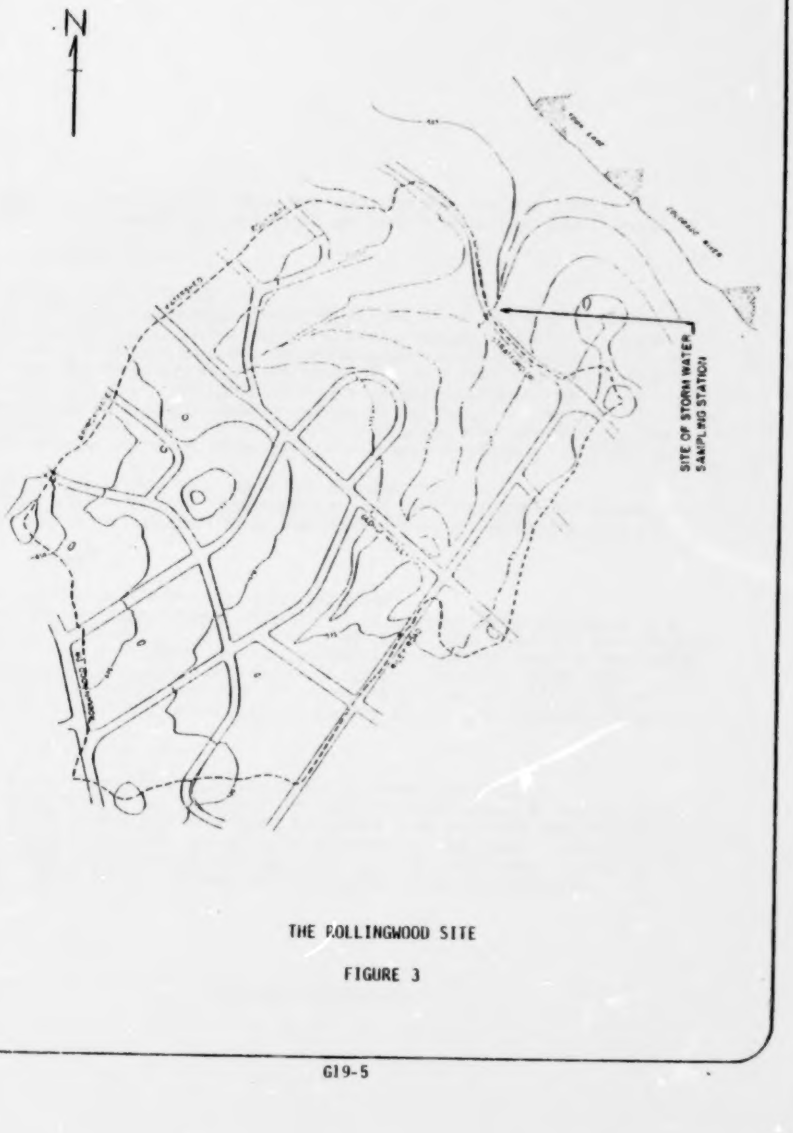
TEXAS NURP PROJECT

FIGURE 1



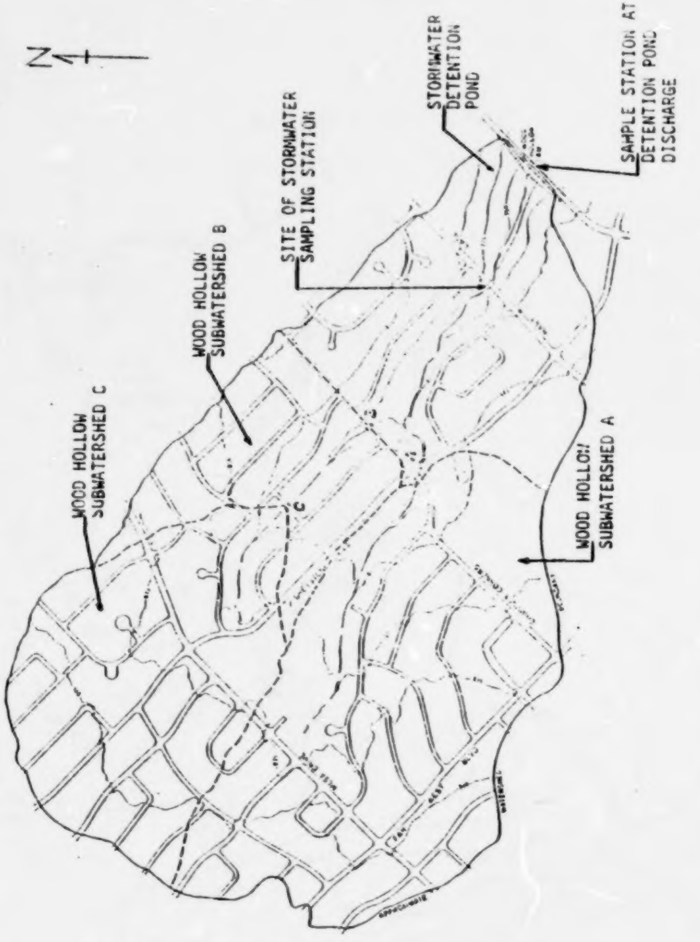
RECEIVING WATER STUDY AREA

FIGURE 2



THE ROLLINGWOOD SITE

FIGURE 3


N
WOOD HOLLOW SUBWATERSHED C
WOOD HOLLOW SUBWATERSHED B
SITE OF STORMWATER SAMPLING STATION
STORMWATER DETENTION POND
SAMPLE STATION AT DETENTION POND DISCHARGE
WOOD HOLLOW SUBWATERSHED A

THE NORTHWEST AUSTIN SITE

FIGURE 4

PHYSICAL DESCRIPTION

A. Area

The City of Austin, situated in Travis County on the Colorado River, is centrally located in the State of Texas. From the Gulf coast, Austin is inland in a Northwesterly direction approximately 175 miles. The total area of the city comprises about 120.6 square miles of land, and about 8.3 square miles of water. Land use within the city is characterized as institutional with associated residential and commercial development.

B. Population

The entire metropolitan area of the City of Austin, comprising the Standard Metropolitan Statistical Area, the urbanized area and the City of Austin, itself, has been increasing rapidly in the last twenty to thirty years. City population, according to the 1980 census, is now 345,500, while it was 186,500 just 20 years ago, an 85% increase. Even if this rate slows down considerably over the next twenty years, urbanization of the Lake Austin watershed, as a desirable area of expansion, will take place.

C. Drainage

Austin's topography consists of gentle rolling hills. The urban area is drained by streams flowing into the Colorado River, which passes through the city and the steeper hills in the Western margin.

The headwaters of the Colorado River are located in Dawson County, near the New Mexico border in midwestern Texas. Some tributaries extend beyond the border, into New Mexico, such as Sulphur Springs Creek, and Wordswell, Seminole and Monument Draw. The river flows in a southeasterly direction across Texas, passing through Austin on its way to the Gulf of Mexico in Matagorda County. The Lake Austin watershed area currently being developed is more hilly, and therefore subject to faster stormwater runoff and the attendant pollution problems, unless adequately controlled by appropriate measures as development in the watershed proceeds.

D. Sewerage System

The existing sewerage system serving the city is separated, with treatment facilities located downstream of the urbanized area and Town Lake.

PROJECT AREA

I. Catchment Name - TX1, 001, Northwest Austin (Hart Lane and Woodhollow Dam sampling stations)

A. Area - 377.7 acres.

B. Population - 3,500 persons.

C. Drainage - This catchment area has a representative slope of 237.6 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 137.3 feet/mile slope and extend 3700 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 31.8 lane miles of asphalt, 100% of which is in good condition. There is no concrete roadway in the catchment.

E. Land Use

365.2 acres (97.3%) is 2.5 to 8 dwelling units per acre urban residential, of which 144.4 acres (39.5%) is impervious.

10.0 acres (2.7%) is > 8 dwelling units per acre urban residential, of which 6.0 acres (60%) is impervious.

2.5 acres (100%) is Shopping Center, of which 1.5 acres (60%) is impervious.

Approximately 40 2% imperviousness in the entire catchment.

II. Catchment Name - TX 1, 003, Turkey Creek

A. Area - 1297 acres.

B. Population - 70 persons.

C. Drainage - This catchment area has a representative slope of 396 feet/mile. There are no curbs and gutters, or swales and ditches. The drainage channel slope approximates 100.3 feet/mile and extends 17,688 feet.

D. Sewerage - Drainage area of the catchment is not served with either separate or combined sewers.

Streets consist of 1.0 lane miles of asphalt, 100% of which is in good condition. In addition there are about 10 lane miles of other material of which 100% is in good condition.

E. Land Use

47.0 acres (3.6%) is < 0.5 dwelling units per acre urban residential, of which 0.9 acres (1.9%) is impervious.

400 acres (30.8%) is Rangeland.

850 acres (65%) is Forest.

III. Catchment Name - TX1, 002, Rollingwood

A. Area - 60.2 acres.

B. Population - 200 persons.

C. Drainage - This catchment area has a representative slope of 260 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 190 feet/mile slope and extend 1270 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 4.5 lane miles of asphalt, 100% of which is in good condition.

E. Land Use

60.2 acres (100%) is 0.5 to 2 dwelling units per acre urban residential, of which 12.9 acres (21.4%) is impervious.

PROBLEM

A. Local Definition (Government)

Lake Austin serves as the primary water supply source for the city; the old water treatment plant on Town Lake is used to supplement the capabilities of the two Lake Austin plants during periods of excessive urban runoff. The Colorado River in the vicinity of the City of Austin has been controlled by dams that result in three consecutive run of the river impoundments. Much of the urbanized area in Austin is in the watershed of Town Lake. As a result, the quality of water reflects to an extent the conditions of urban stormwater runoff.

While the Town Lake watershed is highly urbanized, with high-density residential and commercial development, The Lake Austin watershed has only low-density residential development, and that only in the lower portion. However, the expanding population is forcing development in this watershed, which drains into the primary water supply source. The City of Austin has implemented the Lake Austin ordinance to protect the city's drinking water source. Development must meet minimum standards and/or incorporate adequate runoff control measures. Lake Austin, in addition to being the water supply reservoir, is a popular recreation area.

Data collected by both TDWR and USGS will be used to supplement that collected in this project.

Although preliminary results of the investigation have not demonstrated that urban stormwater runoff is reducing the quality of Town Lake water below a level where it can continue to be used as a drinking water source, added treatment costs have discouraged such use.

B. Local Perception (Public Awareness)

The location of Town Lake, passing through the urbanized area of Austin as it does, makes it highly visible to the general public. Its appearance, attributed to stormwater runoff following rainfall in the watershed of one inch or more, has many people convinced that it should be considered an unacceptable water supply source. The limited results of a public awareness survey also emphasize an awareness of water pollution as an area that needs addressing.

PROJECT DESCRIPTION

A. Major Objective

The City of Austin expects, by quantifying the stormwater quality with respect to the degree of urbanization and specific control measure, it can better understand how to prevent urban stormwater from causing further impairment of the current uses of Lake Austin water. Census figures have shown the rapid rate of urbanization in Austin, which is anticipated to continue, and which will modify the largely undeveloped Lake Austin watershed considerably by the year 2000.

In attaining this objective, the answers to two specific questions are being sought, as follows:

1. How significant are the impacts of the urbanization on stormwater quality?
2. How effective are the control measures for minimizing the impacts?

To determine these answers, a receiving water study and a stormwater sampling program are being conducted.

B. Methodologies

Data on water quality in both Lake Austin and Town Lake have been obtained in the past as part of several city, State and Federal programs. Such data should only be considered to be representative of baseline conditions. Previous sampling efforts have collected very little storm event water quality data in the two watersheds. With respect to hydrology and ambient water quality, these two riverine impoundments function similarly to river systems at times rather than acting as true limnological systems. The almost total dependence on hypolimnetic releases from Lake Travis as the influent waters into the Lake Austin-Town Lake systems ensures that the ambient water quality in these lakes will be a function of the prevailing conditions in the larger lake's hypolimnion as well as on-going limnological processes within the lakes themselves. This close relationship is particularly relevant during the spring and summer months when irrigation demands downstream are greatest and large-scale releases of lake water are commonplace. During the wintertime when flood control considerations predominate, releases through Mansfield Dam are minimal and the ambient water quality conditions throughout the Lake Austin-Town Lake system, particularly for nonconservative constituents, are more variable due to the much longer lake retention times.

Because the waterbodies under study are essentially free from the influences of point source discharges, any observed deterioration in limnological water quality is probably due to nonpoint sources, including storm water runoff from an urbanizing watershed. Even though both riverine lakes are dominated by the water releases from Lake Travis, these lakes offer a contrasting view in terms of the magnitude of urban runoff pollutant loadings. Town Lake is contigous to the major urban area of the city, and runoff events have directly affected water treatment plant operation, bacteriological water quality, and aesthetic considerations. Lake Austin has not undergone such runoff-related impacts to any major extent, although the value of the lake as a water-oriented recreational resource, and as the primary source of drinking water for the Austin metropolitan area, means that similar effects should be carefully avoided.

The primary data sets utilized in the analysis of historical water quality in Lake Austin and Town Lake include: (1) the City of Austin weekly lake samples, (2) the periodic USGS lake sampling program, and (3) daily raw water data on water treatment plant withdrawals from the lakes. All of these monitoring programs will be continuing throughout the NURP study and the data will be utilized to construct the water quality baseline for Lake Austin and Town Lake. For sampling station locations, refer to Figures 5 and 6.

In contrasting the background water quality data in the two lakes, observable differences occurred for water quality parameters such as turbidity, total alkalinity, hardness, total coliforms, and fecal coliforms. Total and fecal coliform differences were attributable to the larger urban runoff loadings in Town Lake; however, hardness and total alkalinity differences, especially during the winter months, were due to the influence of Barton Springs flow contributions into Town Lake. Turbidity measurements exhibited transient increases after storm events, but the magnitude of runoff-generated turbidity is more pronounced in Town Lake than Austin Lake. The limited data on toxic materials, such as pesticides and heavy metals, indicate that few of these materials are detectable in the waters of Lake Austin and Town Lake, and those that do occur are not found in concentrations that might be harmful to aquatic life or the beneficial uses of the water supply. It is possible, however, that the historic sampling for toxic pollutants did not coincide with runoff events, and that these materials are rapidly attenuated within the water column by dilution with Lake Travis waters. Moreover, since most of these pollutants are associated with suspended materials in the water column, there is a distinct possibility that they have accumulated in the sediments.

The receiving water sampling program is being conducted based on the following premises:

(1) The on-going water quality sampling program will be used to provide baseline information on Lake Austin and Town Lake for the more conventional water quality parameters, rather than expending the limited field sampling resources on duplication of effort.

(2) A program for toxics which endanger biota and/or drinking water supplies will be implemented in a stepwise fashion - a preliminary screening at sites where a high potential for occurrence exists, followed by sediment and water sampling to verify the spatial distribution in the lakes. Toxic materials identified during actual runoff sampling in the lake tributaries will have the highest priorities for toxics testing.

(3) The best time for water quality sampling in Lake Austin and Town Lake to determine toxics or other constituents that appear in low concentrations would be during the winter months when the impact of releases from Lake Travis is minimal and lake retention times are longest.

(4) Water quality results from the initial runoff events should be used in defining the parameters of concern for receiving waters, especially when event-oriented sampling is undertaken. The list can be updated if subsequent sampling indicates that other relevant constituents appear on a seasonal basis or exhibit highly variable ambient levels.

(5) Baseline biological samples will be curtailed (i.e., seasonal samples) and the biological sampling program reoriented to "problem" areas where toxics and other water quality parameters might have a biological impact. Pre-event and post event monitoring might still be warranted at sites experiencing significant water quality changes due to urban runoff; however, such monitoring may produce inconclusive information.

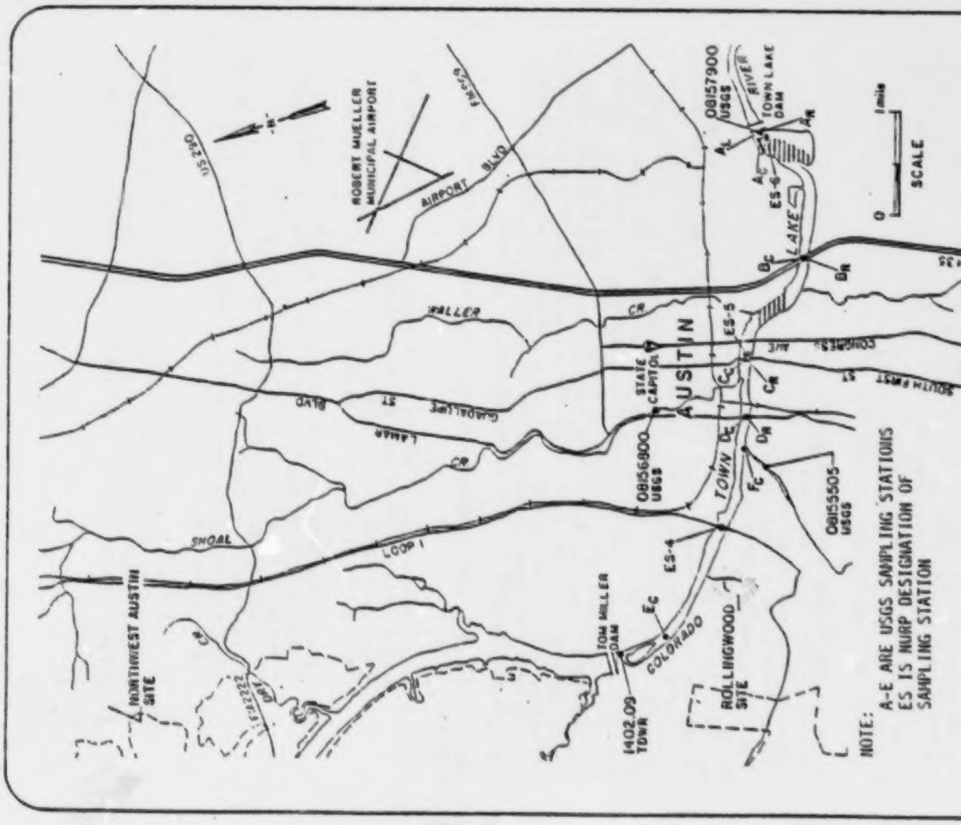
The rationale for sampling site locations is as follows:

(1) In Lake Austin, control stations where the influence of nonpoint source pollution is minimal will continue to be monitored through the existing water quality network, rather than establishing a NURP site there. Hypolimnetic releases from Lake Travis which tend to dictate the overall flow and water quality regimes in the downstream riverine lakes are likely to remain fairly constant on the short-term basis, although the significant seasonal differences in the magnitude of these releases are well documented. On-going water quality monitoring programs below Mansfield Dam will be used since good long-term data records are available and monitoring continues on a frequent basis.

(2) The new station alignment will have sampling points located where they are likely to be influenced by urban-related runoff or septic tank drainage. Since the effects of runoff events are likely to be short-lived in lakes dominated by upstream releases, it is important to locate the sampling sites where the best information can be obtained. With this in mind, the stations will be located at the confluence of major tributaries with both Lake Austin and Town Lake since these are the best sites for nonpoint event-oriented sampling.

(3) Each station will include all relevant vertical dimensions at the sampling site to ensure that samples represent ambient conditions throughout the water column, even when thermal stratification and tributary mixing zones are involved.

The nonevent sampling is limited to a screening function in order to indicate the presence of toxic materials and other constituents which are likely to affect the beneficial uses of lake water. It is imperative that the sampling activities be closely oriented to those environmental areas where the maximum useful information on runoff-related conditions can be obtained. For instance, it would be unwise to enter directly into detailed phytoplankton and macroinvertebrate collection and identification on a lake-wide basis and expect to distinguish between runoff-induced effects and natural environmental variation, given the limited sampling resources available. Although changes in abundance and diversity of these biological indicators has been a useful tool in assessing the effects of point souce loadings on a waterbody, their value as biological measures of runoff-related impacts has yet to be evaluated.

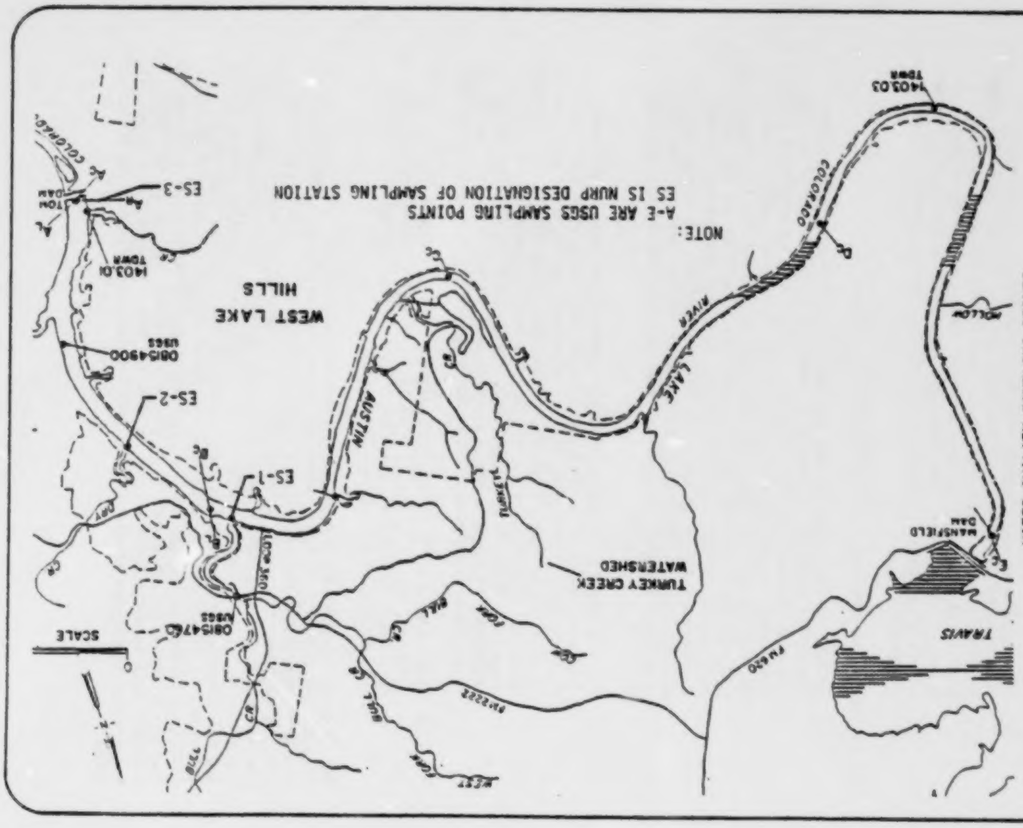


NOTE:
A-E ARE USGS SAMPLING STATIONS
ES IS NURP DESIGNATION OF
SAMPLING STATION

WATER QUALITY SAMPLING POINTS
ON TOWN LAKE

FIGURE 5

G19-14



NOTE:
A-E ARE USGS SAMPLING POINTS
ES IS NURP DESIGNATION OF SAMPLING STATION

WATER QUALITY SAMPLING POINTS
ON LAKE AUSTIN

FIGURE 6

G19-15

The initial nonevent sampling in the receiving waters include water, sediment, and fish tissue sampling from stations in both Town Lake and Lake Austin. Samples are being collected from three stations located in each lake in order to detect the presence of any constituent(s) which may represent potential environmental hazards. Such sampling should provide data on the relative magnitude of ambient pollutant concentrations in these three environmental media. Regardless of whether or not the water samples show significant levels of a given constituent, the long-term accumulations of potentially toxic constituents in the sediments and biomass in the lakes are likely to be revealed by this initial screening, so that appropriate resources can be applied to the assessment of those critical constituents in later stages of the receiving water program.

A single water sample per station (composited from various depths) is being collected to describe the current status of many aqueous constituents within the lake waters, while sediment and fish tissue samples provide data on long-term interactions between certain persistent constituents and the other major environmental media. Two sediment grabs and two adult fish samples are being taken at each of the six field stations for subsequent laboratory analyses. Additional sediment samples are scheduled at two other Lake Austin stations to expand the available baseline on long-term accumulations. Sediments at some major tributaries (primarily in Town Lake) may also be included in this initial screening based on prior monitoring results. The list of those constituents and parameters to be initially investigated in the water, sediment, and tissue samples taken from the lakes is presented in Table 1.

Although the constituent list does not include a majority of the 129 priority toxic pollutants. It does contain the ones whose presence in the lakes have been documented by the ongoing U.S.G.S. lake quality sampling program. A complete priority pollutant analysis will not be included at all in the receiving water study program. Priority pollutant sampling of storm water runoff in tributary watersheds will be used to identify additional substances of concern and to update the analysis list as necessary.

The ultimate direction of the receiving water program for water quality constituents will be related to whether or not toxic materials are encountered in the water, sediment, or biomass samples taken during the screening phase. This flexibility in reorienting the later stages of the receiving water study based upon the results of an initial screening is crucial to the proper conduct of an investigation which will emphasize the effect of runoff pollutant loadings on the ecology of the receiving waters, especially when only minimal ambient levels or sublethal biota responses to the pollutants are expected. Only a small number of toxics have been found in the lakes during previous monitoring efforts, and their ambient concentrations have been very low, so this initial screening process is important to verify the current status with regard to the presence of any toxic materials in the receiving bodies that may threaten Austin's water supply or the other beneficial uses of these lakes. When high environmental levels of a toxic substance(s) are detected, additional sampling to determine the extent of its spatial and temporal distribution in the receiving water bodies may be required, including the use of additional field stations and increased sampling frequency. Similarly, additional biological samples can be taken to determine body burden of the pollutant constituents present in the tissue of different biota groups, or to examine the prevailing resident community structure and diversity for signs of pollutant-related stress.

If the initial screening showed a pattern of toxic material deposited in the sediments, the second phase of the receiving water program would require an expansion of the sediment analysis activities. Sediment samples taken in the deltaic deposits located at the mouths of tributaries would indicate the extent of the toxics distribution in the coarse-grained sediments, while mud samples from the deepest portions of the lakes near the dams reflect the slow accumulations of fine-grained sediments and associated materials. Sediment collection sites would generally be limited to those locations where suspicious levels of one or more toxics previously have been detected.

Storm Event Monitoring

If ambient levels of toxic materials are not sufficient to warrant concern on a long-term basis in areas known to already receive substantial inputs of storm water runoff, then the monitoring of limnological effects from specific rainfall events would gain in importance. During the initial phases, this event-oriented sampling program will receive inputs directly from the storm water runoff analysis efforts to define the probable constituents of concern that are being discharged from local watersheds including both toxics (predominately common pesticides and heavy metals) and nontoxic constituents which are likely to affect the lakes in an observable manner. The available resources of the receiving water program can be placed on event-oriented activities on the lakes which focus on short-term effects by the more conventional constituents present in runoff (i.e., suspended solids, oil and grease, etc.). Rather than representing direct health threats to humans or aquatic biota, as one might expect with toxic materials, the conventional pollutant component of runoff produces secondary environmental effects, such as increasing the treatment cost of drinking water or slightly altering the aesthetic desirability of a recreational water body.

Three or more separate runoff events will be monitored in Lake Austin and Town Lake, primarily from the mouth of major tributaries. It is not practical to sample at the confluence of the same tributaries which have runoff flow and quality monitoring stations in place, because of their relatively small contribution to the lake. Larger tributaries, such as Bull Creek and Dry Creek on Lake Austin or Shoal Creek and Waller Creek on Town Lake are better candidate stations because of the greater magnitude of change that their discharges can introduce into the subject receiving waters. Water quality sampling stations may be located along the midchannel axis of the lake or along the middle of the prevailing discharge plume, whichever spatial pattern best describes the changing pattern of water quality. Furthermore, rather than be composited as in the inital screening samples, water quality samples are to be taken at distinct depths during storm water discharge from tributaries, so that the vertical dimensions of the discharge plume can be represented properly. The initial phase of the biological program will involve laboratory analyses of fish tissue to identify those toxic materials which are found to bioconcentrate in the lake fishes. This approach utilizes the resident fishes as long-term indicators of chronic exposure to low levels of toxic substances that may be present in storm water runoff. When used in conjunction with water and sediment quality data collected during the preliminary sampling effort, this information provides the basis for a comprehensive ecological evaluation of the impacts associated with urban storm water pollution.

TABLE 1

CONSTITUENT ANALYSES TO BE PERFORMED
DURING INITIAL LAKE SAMPLING

Parameter	Environmental Media		
	Water	Sediment	Tissue
General			
Specific conductance, in situ	x		
pH, in situ	x		
Temperature, in situ	x		
Dissolved oxygen (DO), in situ	x		
Sediment volatile fraction		x	
Sediment particle size distribution		x	
Light-Intensity-Related			
Transparency (Secchi disk), in situ	x		
Color	x		
Filter photometer - light extinction, in situ	x		
Organic Pollution			
Five-day biochemical oxygen demand (BOD_5), total	x		
Fecal coliforms	x		
Total chemical oxygen demand (COD)	x		
Total suspended solids (TSS)/turbidity	x		
Total dissolved solids (TDS)	x		
Total organic carbon (TOC)	x	x	
Nutrients			
Nitrate-nitrogen	x		
Nitrite-nitrogen	x		
Ammonia-nitrogen	x		
Total Kjeldahl-nitrogen (TKN)	x	x	
Alkalinity (HCO_3^-, CO_3^-)	x		
Total phosphorus	x		
Dissolved orthophosphate	x		
Metals			
Arsenic	x	x	x
Copper	x	x	x
Lead	x	x	x
Mercury	x	x	x
Zinc	x	x	x
Cadmium	x	x	x
Total Organics			
Total hydrocarbons	x		x
Defoliants			
Total 2,4-D (2,4-dischlorophenoxyacetic acid)	x		x
Total 2,4,5-T (2,4,5-trichlorophenoxyacetic acid)	x	x	x
Total diazinon	x	x	x
DDD		x	
DDE		x	
DDT		x	
Polychlorinated biphenyls		x	x

One of the reasons for limiting the scope of the biological activities is the lack of evidence for biological degradation in the lakes due to pollutant loadings. A multifaceted biological sampling program that includes bacteriological, plankton and macroinvertebrate sampling, primary productively estimates, and fish tissue analyses would be ideal when assessing easily observable environmental problems. However, it would have to be done on a massive scale for the purpose of verifying the more subtle environmental effects. Therefore, the extent of their use in either dry-weather or storm event-oriented sampling will be based on the capacity of these biological parameters to indicate change due to gross runoff loadings or specific constituents in a given nonpoint source discharge.

In order to meet objectives with regard to identifying and assessing those environmental effects induced by urban runoff loadings, it will be necessary to reduce the number of baseline samples aimed at illustrating natural seasonal differences in biota composition and diversity. Also, it may be necessary to conduct some collections without simultaneous detailed water quality analyses (except for the more conventional parameters that are measured in situ) to conserve resources. Biological field samples may be collected initially at each lake station to familiarize the field team with the typical composition and distribution of the biota; however, it would be impractical to develop a systemwide, long-term biological baseline for evaluation of urban storm water effects. An assessment of the more probable short-term limnological phenomena regarding changes in ambient hydrology and water quality conditions following a storm water runoff event in the watershed will often necessitate sampling near the point of maximum effect (i.e., the mouths of major lake tributaries) by implementing component activities of one or more of the original biological work elements. For example, bacteriological quality samples and primary production estimates via experimental setups may be taken in the runoff plume that enters the lake. Plankton and macroinvertebrate collections would likely be omitted during heavy runoff discharge because of the disruptive effect on distribution patterns due to the increased flow velocities.

C. Monitoring

In addition to the receiving water sampling program just described, a storm water runoff sampling program will be conducted. There are 4 sampling sites, for the subwatersheds indicated in Figure 2, and in greater detail for the Northwest Austin and Rollingwood Sites in Figures 3 and 4. The storm rainfall, time-varying flow and water quality data are collected at each of the four r stations for a series of storms. The Turkey Creek site drains directly to Lake Austin, typifying an undeveloped condition. The Rollingwood and Northwest Austin sites are located within Town Lake Watershed, representing low and high impervious cover developments, respectively. The Woodhollow site is below the dam at the outlet of Woodhollow detention pond. The inlet of the pond coincides with the northwest sampling site, (identified as the Hart Lane site.) Under the City of Austin/USGS data collection cooperative program, the USGS has installed automatic water quality samplers in Bull Creek and Shoal Creek basins. Storm event data are being collected at the two stations. These data will also be incorporated into this study.

Storm load will be calculated for each pollutant of significance which was measured during the monitoring. The calculation will permit an evaluation of the relative magnitude of nonpoint source pollutant loads from each of the study areas. The average annual load is to be evaluated from the storm load information and rainfall characteristics, coupling the information developed from the storm sampling with the data obtained from the receiving water study; the existing and potential impacts on Lake Austin/Town Lake water quality and aquatic ecology can be estimated and described.

The cost/benefit of control measures for minimizing the impacts will also be analyzed. The changes in benefits and costs resulting from a given urban runoff control measure determine the merit of the implementation.

Equipment

The instrumentation for storm water quality and quantity sampling is of the automatic type. In addition, for the purpose of measuring runoff event volume, suitable hydraulic control devices were installed at the mouth of each subwatershed being monitored. An HL flume was selected for the Rollingwood site, a triangular broadcrested weir for the Turkey Creek site, and a critical depth meter for the Northwest Austin site.

Controls

The storm water runoff is being monitored at the three subwatersheds, described above. One of the three, Northwest Austin, includes a detention basin which has been incorporated into the study. The other two sub-basins are representative of differing levels of development which will provide information on runoff impacts.

NATIONWIDE URBAN RUNOFF PROGRAM

METROPLAN

LITTLE ROCK, AR

REGION VI, EPA

INTRODUCTION

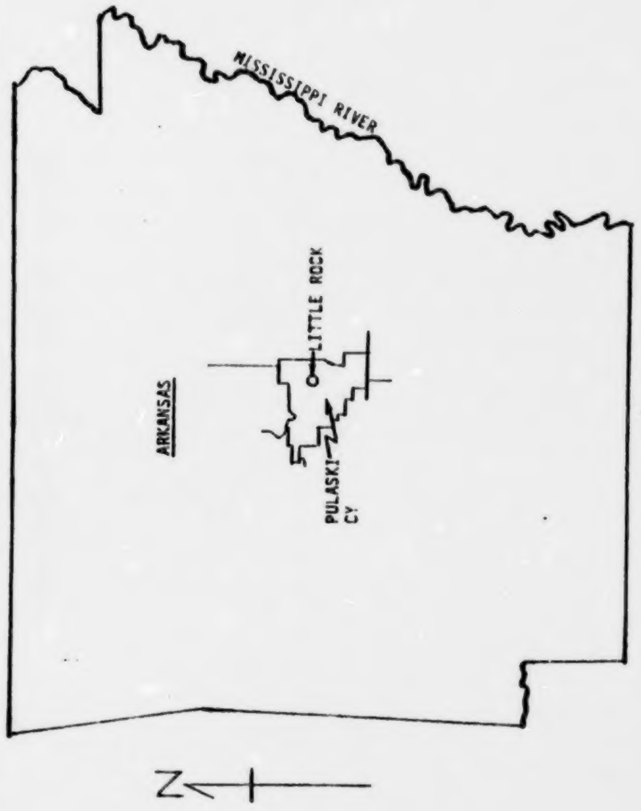
The City of Little Rock, situated in Pulaski County is located in the approximate center of the State of Arkansas. The local topography consists of gentle hills and wetlands, drained by the mainstem of the Fourche Creek, crossing from west to east and entering the Arkansas River, east of the city. The Fourche Creek and its major tributaries drain ninety percent of the urban area.

Upstream of the urban area, Fourche Creek is dominated by rural runoff. Within the urban area the water quality of Fourche Creek has been classified in Use Class B, Fishery Class W. The definition is "suitable for desirable species of fish, wildlife and other aquatic and semi-aquatic life, raw water source for public water supplies, secondary contact recreation and other uses." It will support a warm water fishery. The Fourche, where it passes through the urban area, has been classified as water quality limited.

Areas to the west of the urbanized center of Little Rock are becoming developed. Census figures for 1960, 1970 and 1980 are respectively, 107,800, 132,483 and 158,461. These increases occurred at the rate of 22.9 percent from 1960 to 1970, and 19.6 percent from 1970 to 1980. The rate of increase in population in the Standard Metropolitan Statistical Area between 1970 and 1980 was 21.7 percent. Between 1950 and 1980, this rate was approximately 80%, growing from 220,327 to 393,494. Although growth has slowed down, it appears to be going up close to 20 percent in ten years in both the SMSA and in the City of Little Rock.

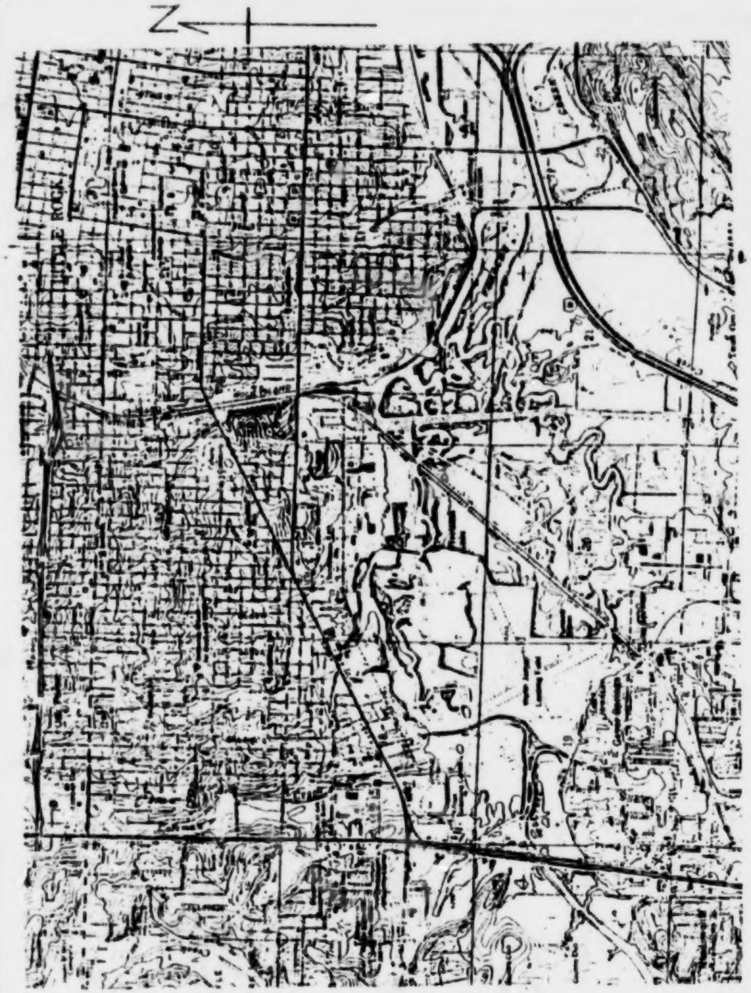
Such growth will continue to increase urbanization during the coming decades. Of concern to local and state agencies are the impacts such continued growth will have on the runoff pollution of Fourche Creek and its tributaries above that already being experienced.

Local agencies are cooperating on this project expecting that evaluation of BMP's will provide information on the most cost-effective, acceptable ways of improving water quality in the Fourche drainage network.



STATE LOCUS
ARKANSAS NURP PROJECT

FIGURE 1



LITTLE ROCK STREETS
USGS QUAD SHEET

FIGURE 2

PHYSICAL DESCRIPTION

A. Area

The City of Little Rock, situated in Pulaski County, is located in approximately the middle of the State of Arkansas. The Arkansas River, following South-Southwest through the area forms a boundary between Little Rock and North Little Rock. The total area to the city comprises about 87.8square miles. Little Rock is the location of the state capitol, and includes forests, agricultural, residential, commercial and some industrial development, along with the University of Arkansas at Little Rock.

B. Population

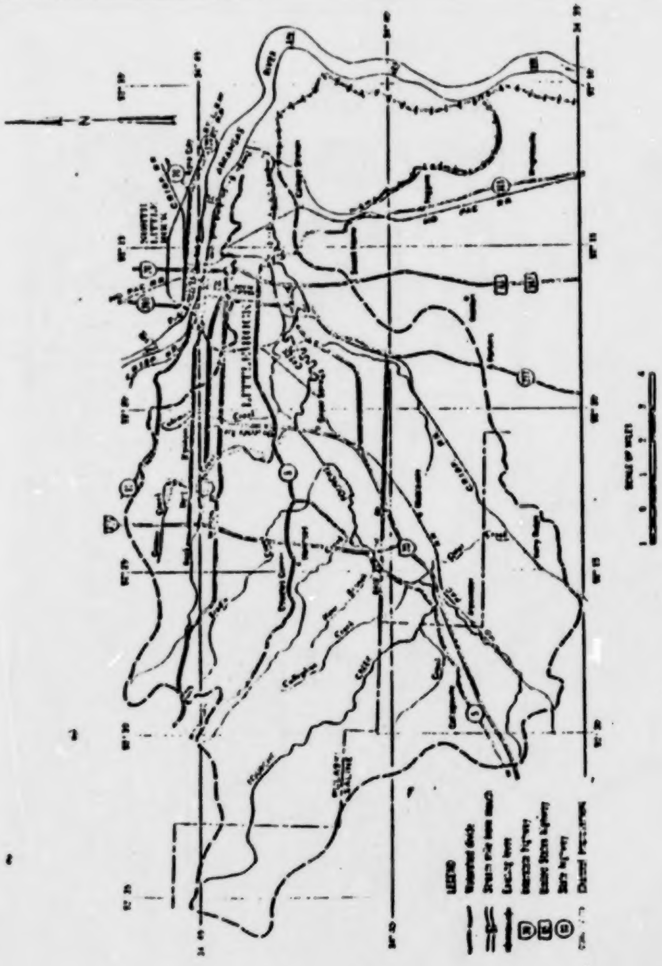
The City of Little Rock population of 158,461, based on the 1980 decennial federal census, is projected to grow about 20% every 10 years. The population in the year 2000 will reach about 190,000, much of the growth accomodated in the upper reaches of the Fourche Creek system.

C. Drainage

The Fourche Creek system flowing generally from west to east, drains 90% of urbanized Little Rock to the Arkansas River. Most of the urbanized area (90-95%) is served with storm drains and curbs and gutters with the remainder served by drainage ditches and swales. In the less developed areas, this percentage drops to about one-third served with curbs, gutter and storms drains. The Arkansas River eventually flows into the Mississippi River.

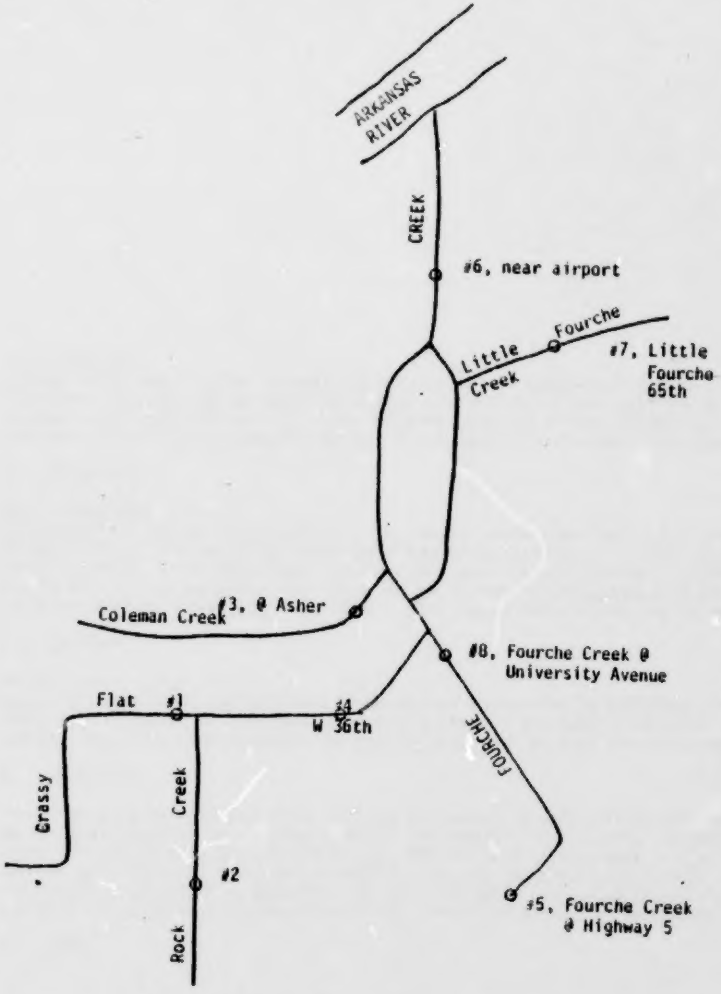
D. Sewerage

The urban area is 100 percent served with a separate sanitary sewer system, or with on-site septic tank systems. Evidence has been uncovered in past studies that some pollutants are entering the drainage network from improperly installed and/or maintained septic tanks. Also, surcharging manholes cause high fecal coliform counts in the streams.



FOURCHE CREEK WATERSHED

FIGURE 3



SAMPLING SITES SCHEMATIC LOCATIONS
FIGURE 4

PROJECT AREA

I. Catchment Name - ARI, Catchment 011, Rock Creek

A. Area - 5,265.4 acres.

B. Population - 537 persons.

C. Drainage - This catchment area has a representative slope of 24.7 feet/mile, 35% served with curbs and gutters and 65% served with swales and ditches. The storm sewers approximate a 24.7 feet/mile slope, and extend 60,720 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 53.5 lane miles of asphalt, 90% of which is in good condition, and the remaining 10% is evenly split between fair and poor condition. In addition there are about 6 lane miles of concrete, also classified percentage-wise the same way.

E. Land Use

444.8 acres (8.4%) is 2.5 to 8 dwelling units per acre urban residential, of which 164.6 acres (37%) is impervious.

19.8 acres (0.4%) is Shopping Center, of which 16.2 acres (82%) is impervious.

12.3 acres (6.2%) is Urban Industrial (light), of which 1.5 acres (12%) is impervious.

175.4 acres (3.3%) is Urban Parkland or Open Space, of which 3.5 acres (2%) is impervious.

405.2 acres is Agriculture.

4,081.9 acres is Forest.

14.8 acres (0.3%) is Water, Reservoirs.

111.2 acres (2.1%) is Barrens.

II. Catchment Name - ARI Catchment 012, Rock Creek

A. Area - 4808.3 acres.

B. Population - 22,875 persons.

C. Drainage - This catchment area has a representative slope of 24.7 feet/mile, 35% served with curbs and gutters and 65% served with swales and ditches. The storm sewers approximate a 24.7 feet/mile slope, and extend 60,720 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 53.5 lane miles of asphalt, 90% of which is in good condition, 5% of which is in fair condition, and 5% of which is in poor condition. In addition, there are about 6 lane miles of concrete, of which 90% is in good condition, 5% is in fair condition, and 5% is in poor condition.

E. Land Use

2629.0 acres (54.7%) is 2.5 to 8 dwelling units per acre urban residential, of which 972.7 acres (37%) is impervious.

605.4 acres (12.6%) is Central Business District, of which 363.2 acres (60%) is impervious.

291.6 acres (6.1%) is Urban Parkland or Open Space, of which 14.6 acres (5%) is impervious.

1,210.7 acres (25.2%) is Forest.

7.4 acres (0.2%) is Water, Lakes.

7.4 acres (0.2%) is Water, Reservoirs.

56.8 acres (1.2%) is Barrens.

III. Catchment Name - ARI Catchment 013, Rock Creek

A. Area - 706.7 acres.

B. Population - 2789 persons.

C. Drainage - This catchment area has a representative slope of 24.7 feet/mile, 35% served with curbs and gutters and 65% served with swales and ditches. The storm sewers approximate a 24.7 feet/mile slope and extend 60,720 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 53.5 lane miles of asphalt, 90% of which is in good condition, 5% is fair condition, and 5% is in poor condition. In addition there are about 6 lane miles of concrete, of which 90% is in good condition 5% is in fair condition, and 5% is in poor condition.

E. Land Use

264.4 acres (37.4%) is 0.5 to 2 dwelling units per acre urban residential, of which 66.1 acres (25%) is impervious.

259.4 acres (36.7%) is Central Business District, of which 220.5 acres (85%) is impervious.

49.4 acres (7%) is Urban Parkland or Open Space, of which 0.5 acre (1%) is impervious.

111.2 acres (15.7%) is Forest.

22.2 acres (3.1%) is Wetlands.

IV. Catchment Name - ARI Catchment 021, Grassy Flat Creek

A. Area - 2433.8 acres.

B. Population - 12,840 persons.

C. Drainage - This catchment area has a representative slope of 32 feet/mile, 90% served with curbs and gutters and 10% served with swales and ditches. The storm sewers approximate a 32 feet/mile slope and extend 21,120 feet.

D. Sewerage - Draiange area of the catchment is 100% separate storm sewers.

Streets consist of 70.9 lane miles of asphalt, 90% of which is in good condition, 5% is in fair condition, and 5% is in poor condition. In addition ther are about 17.7 lane miles of concrete, of which 90% is in good condition, 5% is in fair condition, and 5% is in poor condition.

E. Land Use

1571.5 acres (64.6%) is 2.5 to 8 dwelling units per acre urban residential, of which 581.5 acres (37%) is impervious.

276.4 acres (11.4%) is Shopping Center, of which 226.5 acres (82%) is impervious.

306.4 acres (12.6%) is Urban Parkland or Open Space, of which 15.3 acres (5%) is impervious.

185.3 acres (7.6%) is Forest.

17.3 acres (0.7) is Water, Reservoirs.

76.6 acres (3.1%) is Barrens.

V. Catchment Name - ARI Catchment 022, Grassy Flat Creek

A. Area - 677 acres.

B. Population - 3,516 persons.

C. Drainage - This catchment area has a representative slope of 32 feet/mile, 90% served with curbs and gutters and 10% served with swales and ditches. The storm sewers approximate a 32 feet/mile slope and extend 21,120 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 70.9 lane miles of asphalt, 90% of which is in good condition, 5% is in fair condition, and 5% is in poor condition. In addition there are about 17.7 lane miles of concrete, of which 90% is in good condition, 5% is in fair condition, and 5% is in poor condition.

E. Land Use

410.2 acres (60.6%) is 2.5 to 8 dwelling units per acre urban residential, of which 151.8 acres (37%) is impervious.

54.4 acres (8.2%) is Shopping Center, of which 44.6 acres (82%) is impervious.

66.7 acres (9.8%) is Urban Parkland or Open Space, of which 3.3 acres (5%) is impervious.

123.5 acres (18.2%) is Forest.

22.2 acres (3.3%) is Water, Reservoirs.

VI. Catchment Name - ARI Catchment 031, Coleman Creek

A. Area - 2124.9 acres.

B. Population - 10,624 persons.

C. Drainage - This catchment area has a representative slope of 44.8 feet/mile, 95% served with curbs and gutters and 5% served with swales and ditches. The storm sewers approximate a 44.8 feet/mile slope and extend 22,986 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 19.4 lane miles of asphalt, 90% of which is in good condition, 5% is in fair condition, and 5% is in poor condition. In addition there are about 4.8 lane miles of concrete, of which 90% is in good condition, 5% is in fair condition, and 5% is in poor condition.

E. Land Use

1166.2 acres (54.9%) is 2.5 to 8 dwelling units per acre urban residential, of which 431.5 acres (37%) is impervious.

593.0 acres (27.9%) is Shopping Center, of which
486.3 acres (82%) is impervious.

227.3 acres (10.7%) is Urban Parkland or Open Space, of which
22.7 acres (10%) is impervious.

117.6 acres is Forest

12.4 acres is Water, Reservoirs.

7.4 acres is Barrens.

VII. Catchment Name - AR1 Catchment 032, Coleman Creek

A. Area - 128.5 acres.

B. Population - 89 persons.

C. Drainage - This catchment area has a representative slope of 44.8 feet/mile, 95% served with curbs and gutters and 5% served with swales and ditches. The storm sewers approximate a 44.8 feet/mile slope and extend 22,968 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 19.4 lane miles of asphalt, 90% of which is in good condition, 5% is in fair condition, and 5% is in poor condition. In addition there are about 4.8 lane miles of concrete, of which 90% is in good condition, 5% is in fair conditions, and 5% is in poor condition.

E. Land Use

56.8 acres (44.2%) is Shopping Center, of which
48.3 acres (85%) is impervious.

71.7 acres (55.8%) is Wetlands.

PROBLEM

A. Local definition (government)

The Corps of Engineers is currently developing a local stormwater control project to control flooding in the Fourche drainage system. The study included comments on the necessity for improving Fourche water quality if full benefits to the communtiy are to be realized from that project. The 208 plan identifies urban runoff into the Fourche as the most significant nonpoint water quality problem in the metropolitan area.

Pollutants identified as contributing to water quality problems include excessive fecal and total coliform concentrations, low pH, phosphorus, heavy metals concentrations, low dissolved oxygen levels, and violations of BOD and suspended solids standards.

The flood management program with the Corps of Engineers proposes a 1,750 acre public use area in the Fourche Bottoms in the south part of the city, oriented toward water related activities not supportable given present poor water quality.

B. Local perception (public awareness)

The Fourche system improvement will benefit a large number of residents in less affluent neighborhoods, and minority groups through whose neighborhoods the main stem and its major tributaries flow. Because of recent flood experiences and subsequent increased public awareness of Fourche Creek, proposals have been made to coordinate development to accommodate flood protection and water quality improvement goals. The city, the county, the health department and the local University of Arkansas are all actively participating in various projects dealing with Fourche Creek. Warning signs have been posted on several of the streams, and the public is aware that water quality problems deny some beneficial uses of Fourche Creek.

PROJECT DESCRIPTION

A. Major Objective

Water quality of the Fourche Creek system was identified previously in the 208 plan, and by the Corps of Engineers in the flood protection plan as an area where improvement was needed. The urban runoff contribution to the pollution problem has been identified as a major source.

The Little Rock NURP project, being conducted by Metroplan, a Council of Local Governments, is a continuation of the prior 208 study. In brief, this project will evaluate specific best management practices for effectiveness and cost, and determine the beneficial impacts of implementation of those best management practices determined most cost effective, throughout the drainage system.

During the period from October 1980 to June 1981, the sampling program has collected information during dry weather periods 17 times, producing 891 data points. Rainfall event sampling during the same period was conducted during 13 events. with a total of 2,258 data points obtained. In addition to further sampling, and data analysis, the remaining project efforts will be evaluation of selected best management practices.

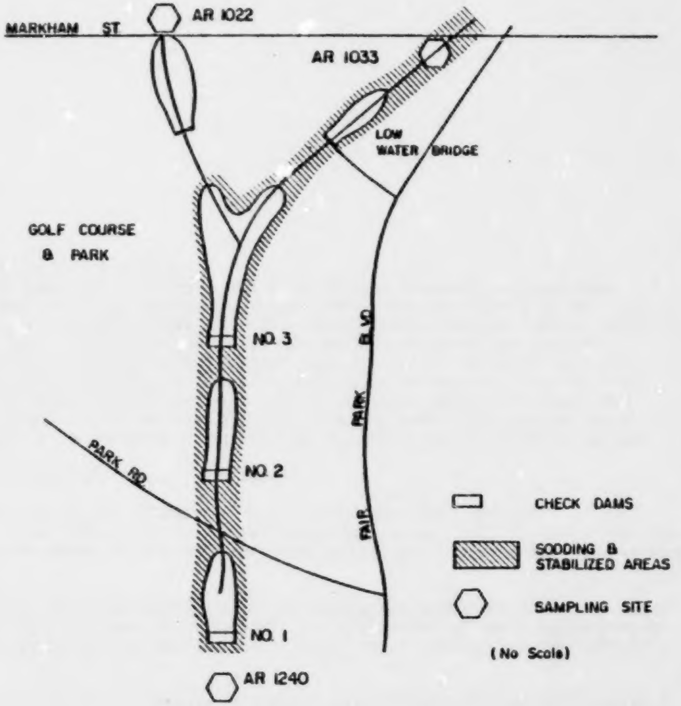
The first year sampling program will be directed at determining background conditions present in the Fourche Creek system. Pollutant loads which are generated by urban stormwater runoff will be developed. Runoff from an isolated watershed with a predominant land use pattern will be sampled to calibrate an urban runoff model storm. After water quality problems have been identified, their sources will be located. Best management practices will be evaluated for effectiveness, the presence of priority pollutants will be determined, and pollutant contributions from the Fourche tributaries to the main stem will be identified.

B. Methodologies

Sampling sites have been selected by the joint efforts of Metroplan and the University of Arkansas, Little Rock (UALR), taking into account accessibility, ability to sample during events, how well runoff represented basin water quality, and ability to determine instantaneoous discharge. Sites selected along the mainstream and on the major tributaries are depicted in the schematic shown as Figure 4. At least seven flow proportional samples will be taken to make up the composite sample, three on the rising leg and four after the peak. The university, utilizing students, is obtaining the samples and performing analyses in compliance with quality assurance and control requirements.

C. Monitoring

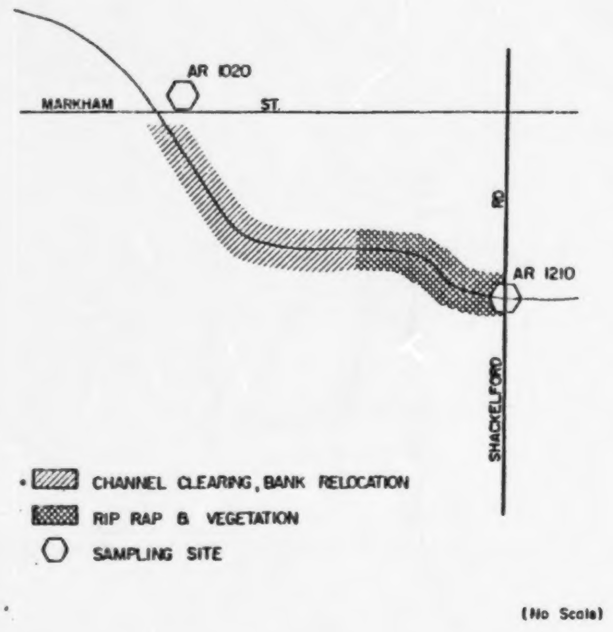
The study area consists of a portion of the Fourche Creek drainage system in Little Rock. In addition to the mainstem, Grassy Flat Creek, Rock Creek, Coleman Creek and Little Fourche Creek are part of the study.



SODDING AND CATCH BASINS

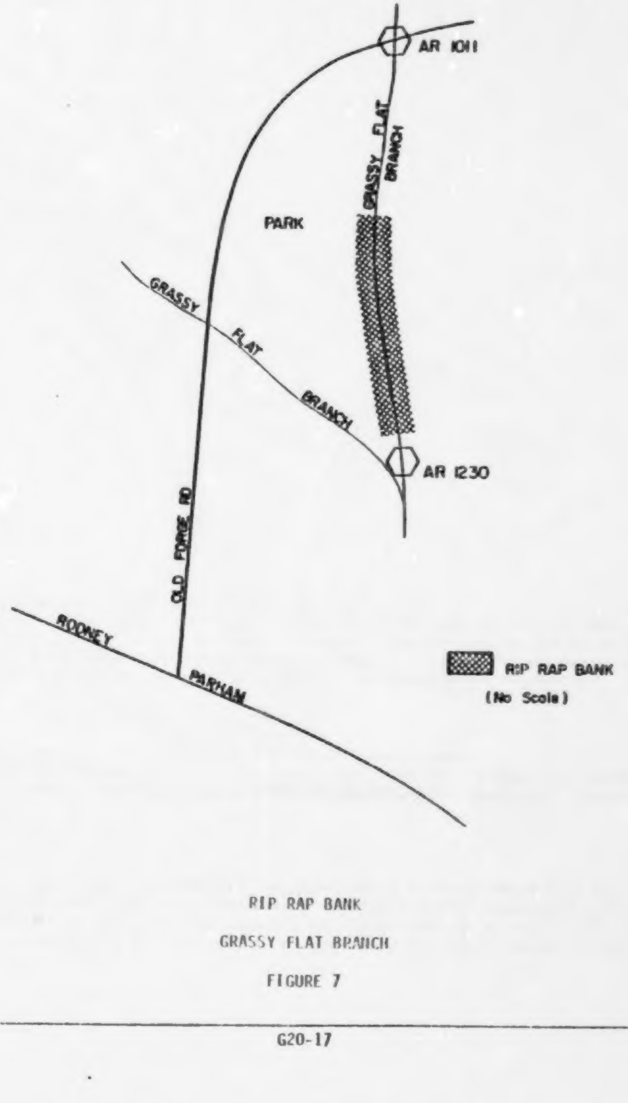
WAR MEMORIAL PARK

FIGURE 5



STABILIZATION OF ROCK CREEK

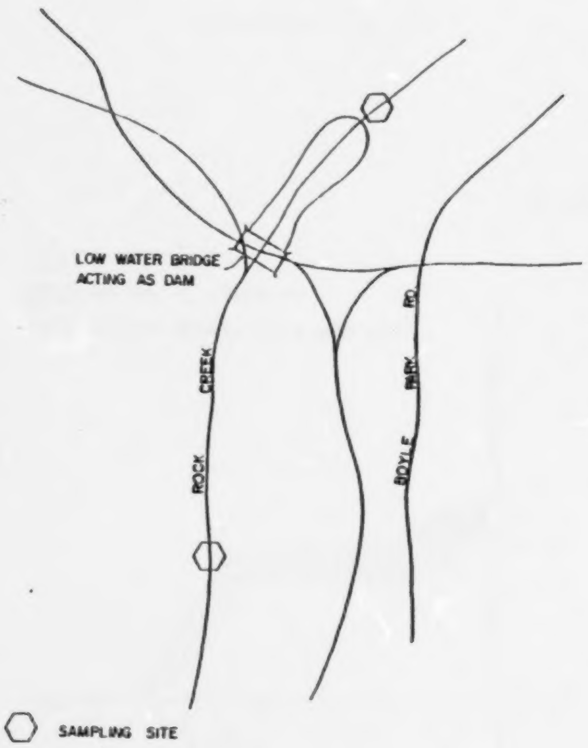
FIGURE 6



RIP RAP BANK

GRASSY FLAT BRANCH

FIGURE 7



LOW WATER BRIDGE ACTING AS DAM

ROCK CREEK, BOYLE PARK

FIGURE 8

The list of parameters and consituents examined in each sample includes: BOD_5, total suspended solids, total phosphorus, total nitrogen, fecal coli, lead, zinc, chromium, aluminum, chemcial oxygen demand, dissolved oxygen, rainfall, flow, and temperature. For a few samples, the presense of priority pollutants will be analysed.

D. Equipment

For this project no automatic water sampling equipment was installed. Rather, students at the university were utilized to obtain the grab samples and record field conditions in accordance with the established schedule.

Controls

Following completion of the first year program of background sampling, a determination was made with regard to which types of best management practices would be used. The decision was made to evaluate the benefits gained by seeding, sodding, retention basins, and bank stabilization with rip rap and gabions. Their locations are shown schematically in Figures 5-8.

NATIONWIDE URBAN RUNOFF PROGRAM

MID-AMERICA REGIONAL COUNCIL

KANSAS CITY, KANSAS AND
INDEPENDENCE, MISSOURI

REGION VII, EPA

INTRODUCTION

The Water Quality Management 208 Final Plan for the Kansas City Metropolitan Region concluded that "specific sources of nonpoint source pollution in the 208 area have not yet been identified" and that additional information must be collected to identify the nonpoint sources, determine their impact on water quality, and develop control measures. Because of the large size of the Kansas City Metropolitan Region (4000 square miles), nonpoint source monitoring was not performed in the original 208 program. Instead, nonpoint source loadings were calculated using loading functions.

The impact of urban runoff on water quality in the Kansas City Metropolitan Region has not been intensively studied. However, both Indian Creek and Rock Creek appear to have water quality problems. Results of several years of macroinvertebrate study on Indian Creek indicate that stressed conditions exist in stream reaches receiving urban runoff. There are no existing water quality or biological data for Rock Creek, but visual observations indicate that water quality in Rock Creek is adversely affected by urban runoff. Large amounts of debris, transported by stormwater runoff and high stream flow conditions, is present in Rock Creek.

The primary objective of the Kansas City NURP Study is to document the magnitude and sources of urban runoff loadings to Indian Creek and Rock Creek and to determine their impact on water quality and biota.

PHYSICAL DESCRIPTION

A. Area

The Kansas City metropolitan region, located at the confluence of the Missouri and Kansas rivers, has grown from a small fur-trading settlement to a sprawling metropolitan region that is home to more than 1.3 million people. The area covers nearly 4,000 square miles.

Until the end of World War II, most development in the metropolitan area occured in a semi-circular core area south of the Missouri River that includes the central business districts of the two Kansas Citys. At this time, the core area was the most dominant sector. In recent decades, however, most development has occured outward from the core and along major transportation corridors. Freeway access and annexations by local governments, which provide urban services and facilities, have encouraged such suburban development. This suburban growth has occured primarily in Johnson, Platte, and Clay counties.

Residential development occupies more than 54% of the acres in urban use in 1973. The predominant residential use is the single family dwelling.

The topography, soils and water resources of the region are the most significant aspects of the region's physical environment. A large portion of the region is composed of gently rolling hills with elevations ranging from 690 feet to 1200 feet. There are numerous areas of steeps slopes and low-lying flood plains, where care must be taken if development is to occur.

The surface water resources of the region are various. Within the region, numerous creeks and streams drain into the Missouri and Kansas Rivers. In addition, there are eleven major man-made lakes of fifty surface acres or larger.

B. Population

According to population projections adopted by Mid-America Regional Council, future growth is expected to occur in surburban areas, primarily in Johnson, Clay, Platte, and eastern Jackson counties. Urban land use is projected to increase by more than 30 percent by the year 2000.

C. Drainage

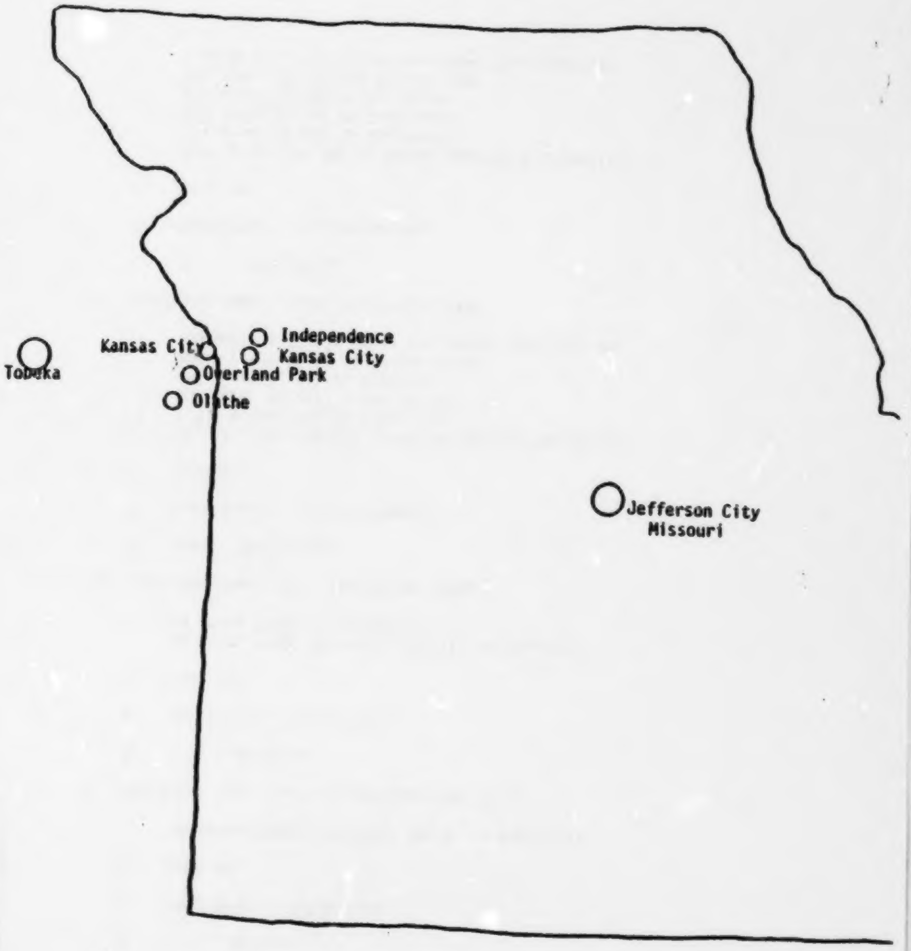
The study is taking place in two separate drainage areas in two different states.

Indian Creek, in Johnson County, Kansas orginates near Olathe and flows pass the urbanizing area of Lenexa and Overland Park into the Blue River. Indian Creek drains one of the most rapidly developing areas in the Region. Slopes range from mild to moderate. Land use ranges from low to medium density residential, shopping centers and light industrial. The average number of rain events for the period 1960 to 1976 is over 100 per year, with a mean annual rainfall of 38.8 inches.

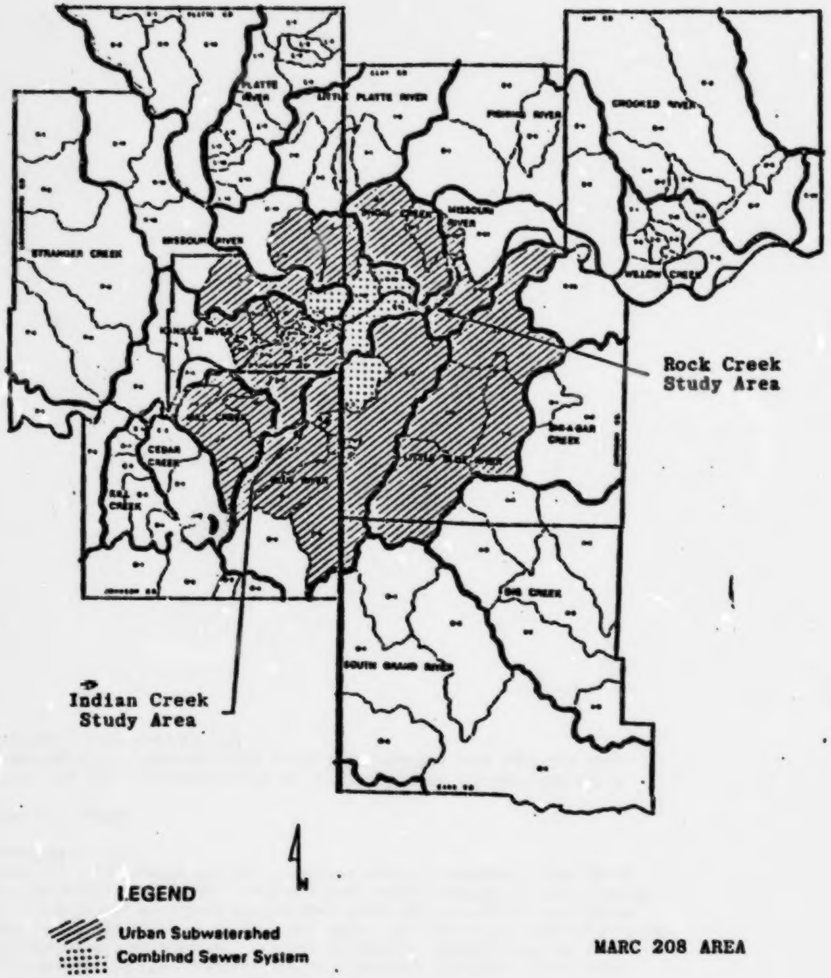
Rock Creek, in the city of Independence, Missouri forms its headwaters in southwest Independence and flows north into the Missouri River just below the mouth of the Blue River. Rock Creek drains an area of 9.2 square miles in the southwest and west parts of the city. Rock Creek has many small tributaries. It has an average channel width of 30 feet, and an average slope of 40 feet per mile. The watershed contains moderate to steep sloes, resulting in frequent flooding of urban areas adjacent to the creek. The study area has a mean annual rainfall of 40.64 inches. Land use is primarily old low to medium density residential and strip commercial.

D. Sewerage System

There are some combined sewers in the Mid-America Regional Council's planning area. However, both areas being studied have separate sewer systems. (see Figure 2.16)



THE STATES OF KANSAS AND MISSOURI



MARC 208 AREA

PROJECT AREA

Rock Creek Study Area

I. Catchment Name - Rock Creek Residential Site (RR)

A. Area - 58 acres.

B. Population - 457 persons.

C. Land Use

58 acres (100%) is Medium Density Residential.

II. Catchment Name - Rock Creek Commercial (RC)

A. Area - 36 acres.

B. Population - 122 persons.

C. Land Use

18 acres (50%) is Medium Density Residential
18 acres (50%) is Commercial

III. Catchment Name - RS 1 (In-stream Site)

A. Area - 3045 acres.

B. Population - 25,197 persons.

C. Land Use

18,797 acres (74.6%) is Medium Density Residential
1,260 acres (5%) is Commercial
806 acres (3.2%) is Industrial
957 acres (3.8%) is Parkland
3,276 acres (13%) is Vacant Land
100 acres (.4%) is Urban Area Under Construction

IV. Catchment Name - RS 2 (In-stream Site)

A. Area - 4624 acres.

B. Population - 40,190 persons.

C. Land Use

3436 acres (74.3%) is Medium Density Residential
203 acres (4.4%) is Commercial
102 acres (2.2%) is Industrial
305 acres (6.6%) is Parkland
569 acres (12.3%) is Vacant Land
9 acres (.2%) is Urban Area Under Construction

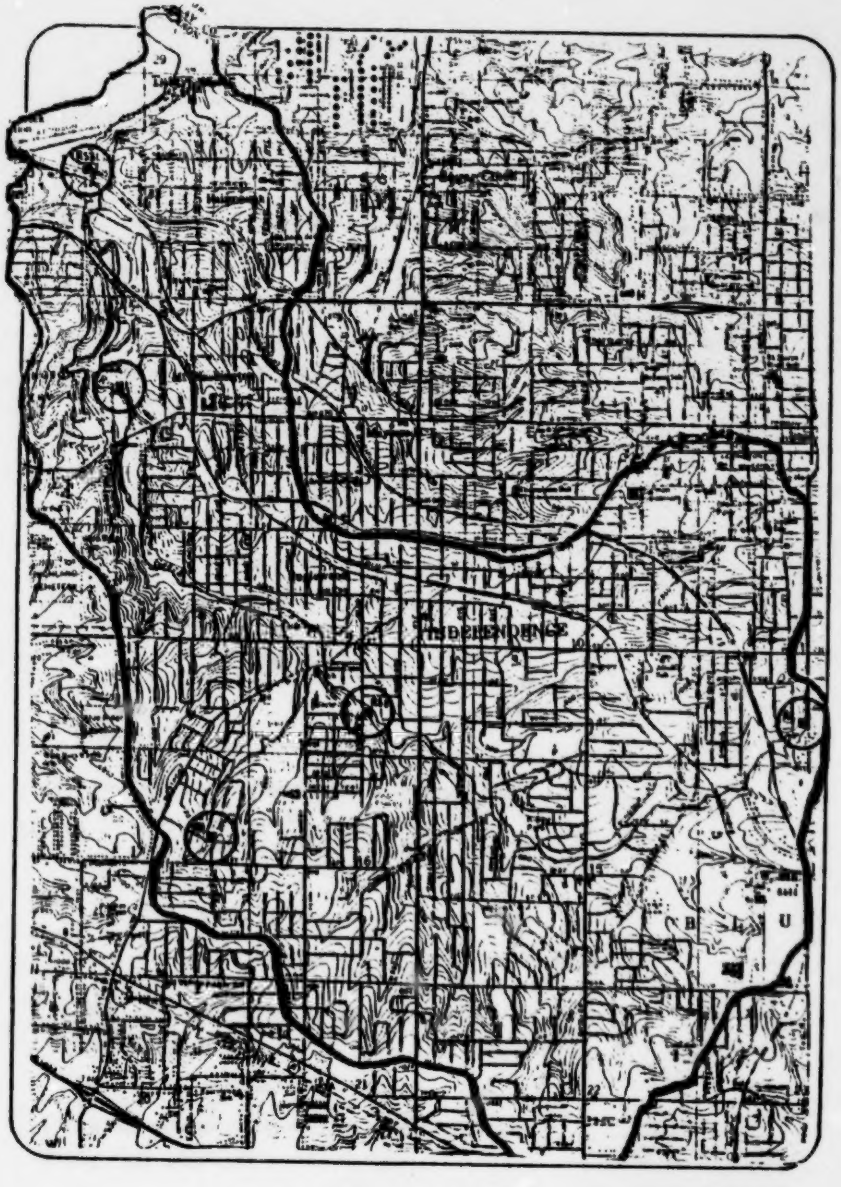
V. Catchment Name - RS 3 (In-stream Site)

A. Area - 5566 acres.

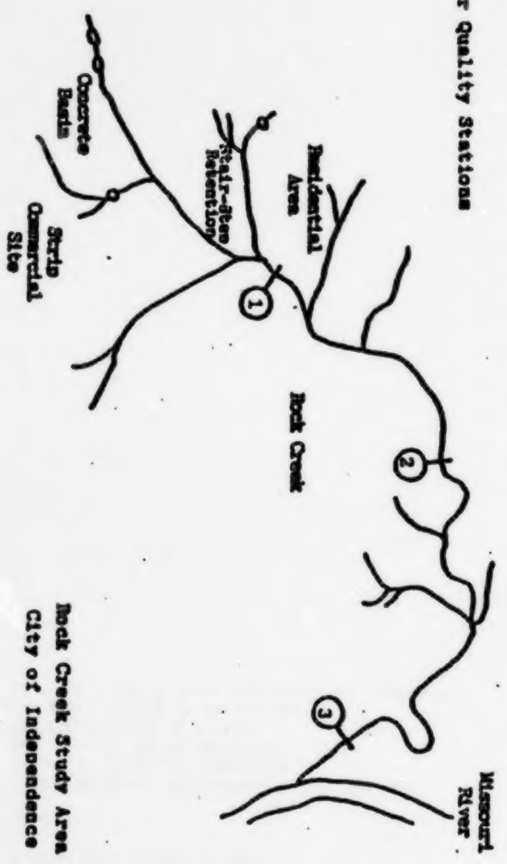
B. Population - 51,237 persons.

C. Land Use

4,035 (72.5%) is Medium Density Residential
245 acres (4.4%) is Commercial
100 acres (1.8%) is Industrial
412 acres (7.4%) is Parkland
763 acres (13.7%) is Vacant Land
11 acres (.2%) is Urban Area Under Construction



INDEPENDENCE, MO STUDY SITES



Rock Creek Study Area
City of Independence

Indian Creek Study Area

I. Catchment Name - Indian Creek Commercial Site (IC)

A. Area - 58 acres.

B. Land Use

55.7 acres (96%) is Commercial
2.3 acres (4%) is Vacant Land

II. Catchment Name - Indian Creek Light Industrial Site (II)

A. Area - 72 acres.

B. Land Use

40.3 acres (56%) is Industrial
31.7 acres (44%) is Vacant Land

III. Catchment Name - Indian Creek Residential (IR)

A. Area - 63 acres.

B. Land Use

56 acres (89%) is Medium Density Residential
2 acres (3%) is High Density Residential
5 acres (8%) is Parkland

IV. Catchment Name - IS 1 (In-stream Site)

A. Area - 11,005 acres.

V. Catchment Name - IS 2 (In-stream Site)

This site is currently being moved.

VI. Catchment Name - IS 3 (In-stream Site)

A. Area - 16,862 acres.

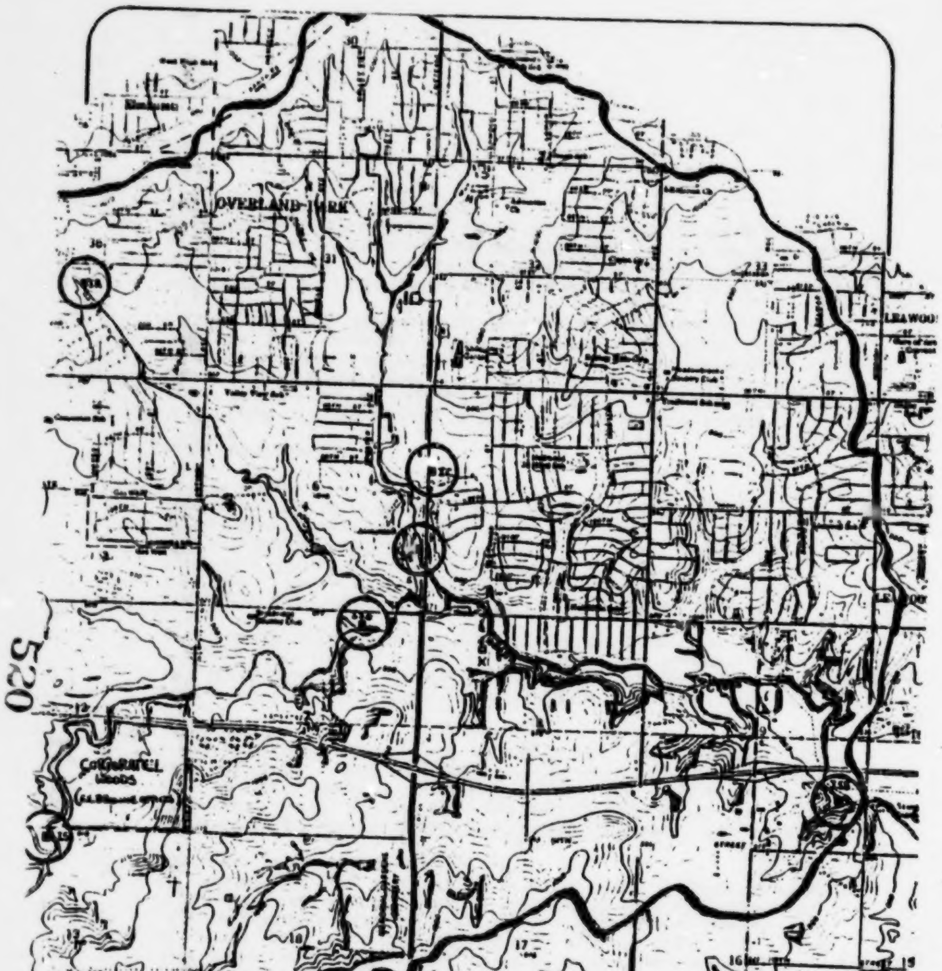
VII. Catchment Name - IS 4 (In-stream Site)

A. Area - 1372 acres.

VIII. Catchment Name - IS 5 (In-stream Site)

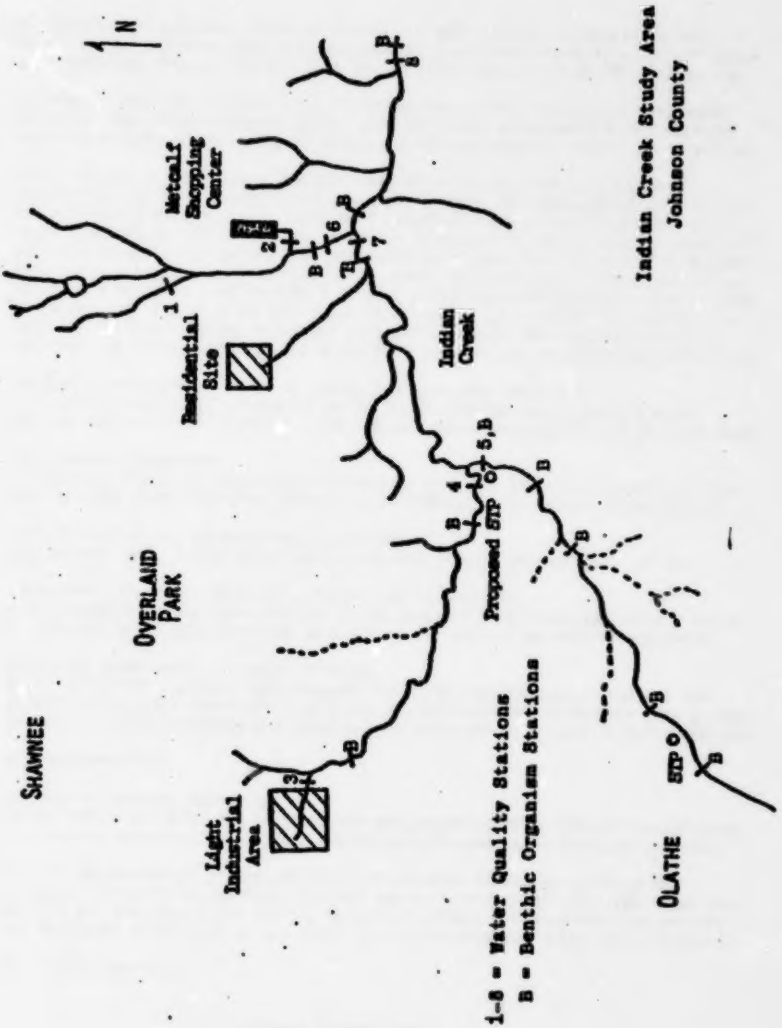
A. Area - 23,941 acres.

Note: All fixed site data was not submitted in time for inclusion in this report.



CONTRIBUTING DRAINAGE AREA & MONITORING SITES, INDIAN CREEK

G21-12



G21-13

PROBLEM

A. Local definition

The impact of urban runoff on water quality in the Kansas City metropolitan region has not been intensively studied and, thus quantitative water quality data are not available to assess the impact of water quality problems. Result of several years of macroinvertebrate study on Indian Creek indicate that stressed conditions exist in stream reaches receiving urban runoff. The macroinvertebrate data indicate that the only point source discharge to the Indian Creek study area does not adversely affect the macroinvertebrate population in the urbanized area.

There are no existing water quality or biological data for Rock Creek, but visual observations indicate that water quality in Rock Creek is adversely affected by urban runoff. Throughout the study area there is evidence of sewer streambank erosion and sediment deposition. Large amounts of debris, transported by stormwater runoff and high stream flow conditions is present in Rock Creek.

Johnson County is also interested in collecting urban runoff data for input into the 201 facilities plan for the Indian Creek watershed. A wastewater treatment plant is proposed and the urban runoff data may have a significant impact on the degree of treatment required at the proposed plant.

The city of Independence also has some very specific objectives for the NURP study. The city will be performing their own stormwater management study encompassing the entire 78 square mile area. However, their study will last only 16 months versus 36 months for the NURP study. The city is interested in transferring the results of the NURP study to help calculate the hydrological characteristics of Independence and develop stormwater control methods.

B. Local perception

Indian Creek in Johnson County is highly visible to the residents. The stream is classified as a class B stream. This means the waters must be protected for secondary contact recreation, the preservation and propagation of desirable species of fresh warm water aquatic biota, public water supply, industrial water suppy and agricultural purposes. In Johnson County the citizens seem to be interested in the water quality of the creek.

Rock Creek is not classified by Missouri since it is considered an ephemeral stream. The creek does seem to be affected by stormwater runoff as evidenced by the areas of severe erosion and sedimentation, and from the large amounts of debris found in the stream. The main concern with the citizens of Independence seems to be flooding.

PROJECT DESCRIPTION

A. Major Objective

The principal objectives of the study are to characterize urban runoff loadings by land use and define the sources of the pollutants, to determine the impacts of urban runoff on stream water quality and biota and to evaluate the effectiveness of sedimentation basins and ponds in reducing urban runoff pollutants.

The project objectives are being accomplished by monitoring specific land uses in the two study areas and by in-stream monitoring of water quality during both dry and wet weather conditions.

B. Methodologies

Automatic flow measurement and sampling equipment was installed at eight stations in the Indian Creek Watershed. Three of the stations are to measure runoff from three land uses. Five of the stations are in-stream stations to measure the impact of urban runoff on water quality.

In the Rock Creek Watershed two stations were installed to measure stormwater runoff from different land uses and three stations were installed on Rock Creek to measure the impact of urban runoff on water quality.

Dry weather data is also being collected once a month and analyzed for the same parameters as the wet weather samples.

Base or "low flow" pollutant loads will be calculated for each stream station in order to determine the relative magnitude of loads generated during low flow and during rain events.

The wet weather data (rainfall, flow and mean event concentrations) will be used to develop load-runoff relationships that characterize the resulting water quality from different types of storms and different land uses.

The land use runoff data will be analyzed using a method developed by Browne and Bedient. Graphs of areal pollutant loadings in pounds per acre versus runoff in inches over the land use area will be developed for various parameters. The slope of a straight line through a plot of total pollutant loading versus runoff will yield a pollutant concentration in pounds per acre-inch. The slope of the line can be expressed in units of concentration. Mean concentrations developed using this method can be applied to runoff from other areas of similar land use to calculate runoff loadings based on a knowledge of the runoff volume. An attempt will be made to correlate the data to other characteristics such as soil type, average slope, rain intensity, rain duration and peak storm flow.

Post-storm sampling data will be used to study the recovery mechanics in action as the stream returns to base flow. Processes such as sedimentation, nutrient transport, and precipitation will be emphasized during analysis of this data.

The stormwater quality results from the in-stream data will be analyzed in two ways. First, concentration distributions will be constructed with the composite concentrations from each storm to search for any temporal or spatial trends.

Particular attention will be paid to the difference between land uses. The second analysis to be performed will calculate a total storm load (in lbs.) from each storm. This calculation will be performed by multiplying the composite concentrations and the total discharge of direct runoff. The amount of direct runoff will be determined by using a base flow separation technique on the hydrograph from the flow meters. The actual procedure for calculating the amount of direct runoff will consist of counting the marks made on the strip chart that represent a sample being taken. These marks represent a pre-set volume of runoff and will be used to calculate total flows. Annual loads from the catchments above each station will be calculated for each parameter.

Relationships from the load-runoff relationships and the statistical analysis of the data will be used to predict urban stormwater quality in other areas of the Midwest Region. Key parameters in these relationships will be catchment size, type of land use and basic geomorphic data such as slope and soils. Using these basic factors from a small subdivision or small industrial catchment to a large urban watershed, the annual pollutant loads for different parameters can be predicted.

The model will also be used in the City of Independence stormwater study.

C. Monitoring

Automatic flow recording and sampling equipment was installed at each station. The sampler is programmed to collect an equal volume sample for every programmed volume of water that flows by the station. The resulting composite sample is analyzed in the laboratory. The sampling system is activated during a storm event by a mercury float switch set at a predetermined water level for each site. The method will produce a volume-proportioned composite sample.

Dry-wet fallout samplers are being used to measure bulk precipitation.

Following is a list of the monitoring sites and the equipment available at each site (see maps).

Indian Creek

Indian Creek Residential Site (IR) - The catchment being monitored contains a trapezoidal concrete channel that receives direct runoff from back yards. An H-flume was installed to calculate flow. A Sigma-Motor automatic sampler and ISCO flow meter are installed.

Indian Creek Commercial Site (IC) - This site contains 3 pipes draining a commercial parking lot into a concrete channel. A cutthroat flume is installed to calculate flow. A Sigma-Motor automatic sampler and ISCO flow meter are installed.

Indian Creek Light Industrial Site (II) - This monitoring station is located at the outfall of a 66 inch reinforced concrete pipe which discharges to a rough concrete apron. A Palmer-Bowlus flume was installed to calculate flow. A Sigma-Motor automatic sampler and ISCO flow meter are installed.

Indian Creek In-Stream Sites (IS 1-IS 5) - The instream sites all have Sigma-Motor automatic samplers and ISCO flow meters installed. Rating curves were developed for the sites.

Rock Creek

Rock Creek Residential Site (RR) - This site is located at a road crossing of a 42 inch reinforced concrete pipe. There is a free discharge point off an apron at the downstream end of the culvert. An H-flume was installed at this point. A Sigma-Motor automatic sampler and ISCO flow meter were installed.

Rock Creek Commercial Site (RC) - This site is a 27 inch pipe draining into a 30 inch pipe, accessible only thru a manhole. A flume was installed to measure flow. A Sigma-Motor automatic sampler and ISCO flow meter were installed.

Rock Creek In-Stream Sites (RS 1-RS 3) - RS 1 has a USGS float type flow gage with a five minute punched paper tape recorder. A broad crested weir is used to provide a suitable control section. RS 2 has a rating curve available also. RS 3, located at the wastewater treatment plant pumping station, has a rating curve also. All instream sites are equipped with Sigma-Motor automatic samplers and ISCO flow meters.

D. Controls

The Best Management Practice Monitoring program will be designed after preliminary results from the problem assessment phase are analyzed. It is planned that one detention basin or similar BMP will be monitored to evaluate pollutant removal efficiencies.

NATIONWIDE URBAN RUN-OFF PROGRAM

DENVER REGIONAL COUNCIL OF GOVERNMENTS

DENVER, CO

REGION VIII, EPA

INTRODUCTION

The Denver Regional Council of Governments Clean Water Plan completed under Section 208 of the Water Pollution Control Act Amendments of 1972 (P.L. 92-500, Section 208) identified nonpoint source loadings as a significant contribution to receiving water pollution through computer simulations of the South Platte River basin and its major tributaries as it passes through the Denver Metropolitan Region.

The Denver urban runoff project is a relatively unique project as the climatic and water use/reuse conditions imposed by a semi-arid climate and highly erodible soils combined with significant irrigation withdrawals and return flows, make the study area highly complex. Additionally, the historic flows in the river channel have been highly modified by the construction of flood control and water supply reservoirs on the mainstem and tributaries. As a result of these constraints, the relationship between urban nonpoint sources loadings and receiving water quality are much different than more humid areas.

Nonpoint sources of pollution occurring as urban runoff are a significant source of receiving water quality pollution in the Denver region. However, due to the uncertainties of the effectiveness of control measures on nonpoint sources, the benefits to be accrued by local governments, and the cost and institutional difficulties surrounding an implementation program, the 208 Clean Water Plan recommended that additional studies and data were needed. The Denver NURP project was initiated to fill in these data gaps.

PHYSICAL DESCRIPTION

A. Area

The Denver area is typical of many communities and areas of the nation that are located in a semi-arid climate. In such areas, the rainfall is sporadic both in time and in intensity. The Denver area receives approximately 16 inches of precipitation per year with over 300 days per year of sunshine. Because of meteorological conditions in the Denver are, there are periods of many weeks during a year when precipitation is negligible or zero.

The Denver area streams are greatly affected by urban runoff. While precipitation occurs on only about 15% of the days of the year, individual storms are typically of short duration and high intensity. Many of the urban drainage areas in the region have steep slopes which, in combination with intense rainfalls of short duration, yield low times of concentration and high overland and gutter flow velocity heads.

Streams provide little dilution of urban runoff events occuring during the low flow periods of the year. During dry periods, runoff from various urban land uses when storms do occur appear to be causing instream water quality problems due to the extreme low flows experienced at these times.

B. Population

The Denver regional area presently has a population of approximately 1.6 million people. It is forecasted that the population in the year 2000 will 2.35 million. This growth will be occurring to a great extent in response to the nation's commitment to become energy independent. Denver is the focal point for major development of energy resources such as coal, oil, gas and oil shale during the foreseeable future.

C. Drainage

The South Platte River originates in the continental divide and flows through the South Park area of the Rocky Mountains. It funnels through hard bedrock to the foothills of the mountains. When it breaks out of the foothills onto the plains, it enters Denver proper. The actual natural boundaries of the South Platte includes about 3000 square miles of land.

The South Platte River basin study area, as defined, is approximately 120,000 acres (187 square miles). Elevation ranges from 5,140 feet to 7,965 feet above mean sea level. The downstream reach of the South Platte River is characterized by a broad alluvial flood plain with a gravel channel. This condition also characterizes the furthest upstream reach at Littleton. Between these points, the stream channel of the South Platte River varies from a hard bedrock to depositional areas with much accumulated sediment.

The study area lies in a piedmont basin, with high plains to the east and foothills to the west. The topography is gently rolling with drainage and ridgelines trending generally between east-northeast and west-northwest. The predominant weather patterns and winds are from the west, however, frontal storms approach from the southeast or northeast. The climate is semi-arid with 14-15 inches of precipitation annually.

Figure I is a map of the Denver area showing the location of the study area within the South Platte River basin. That portion of the main stream channel sampled is 14.5 miles long and drains generally in a northerly direction. Three dams built by the U.S. Army Corps of Engineers exert a control over the river flow and define boundaries of the surface runoff basin area. Chatfield Dam is located on the South Platte River approximately 20 miles south of Denver. It is operated as a flood control and recreational reservoir by the Corps of Engineers and normally releases water in an amount equal to its flow, although sometimes abrupt changes are made in release from day to day. Mt. Carbon Dam is located in the southwest part of the region on Bear Creek and is operated similarly by the Corps of Engineers. Cherry Creek Dam impounds a reservoir on Cherry Creek which has released water downstream only two times in the past ten years.

D. Sewerage System

The Denver area did have combined sewers until approximately 20 years age. These have since been separated and the area is served entirely by separate storm sewers.

There are storm sewers only in the downtown area. In the residential areas the drainage is all through curbs and gutters and street drainage.

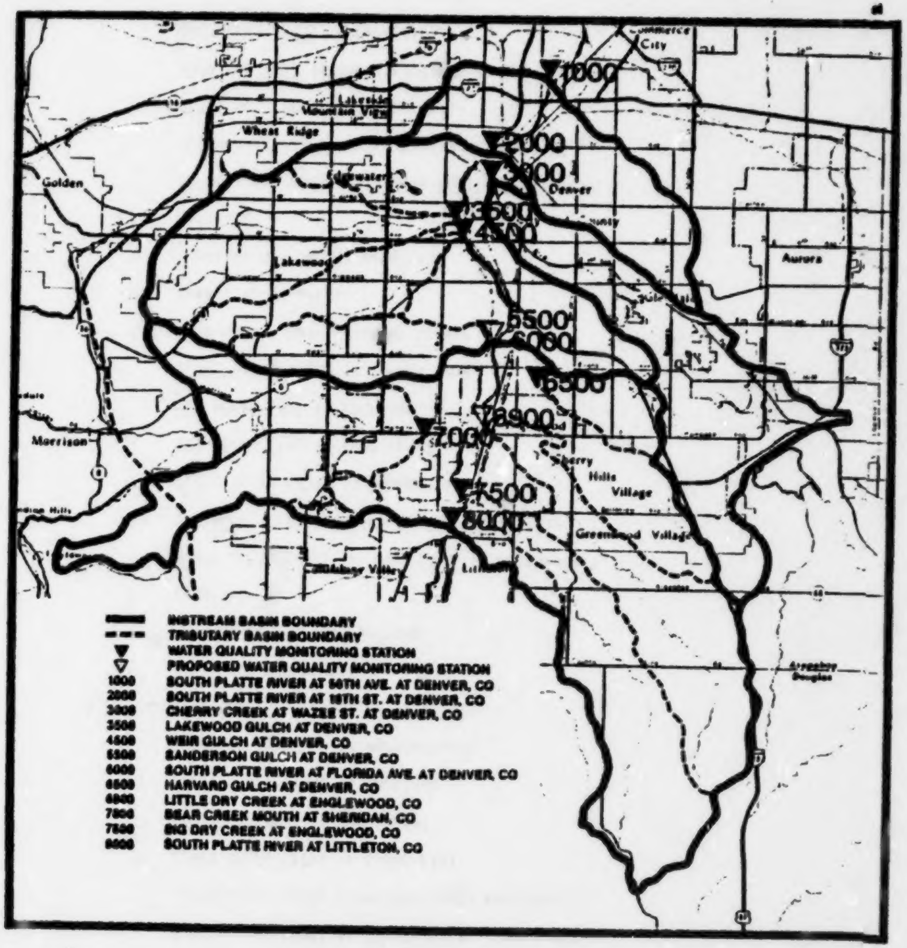

Commerce City
1000
Lakeside
Mountain View
Wheat Ridge
2000
3000
Denver
Golden
Edgewater
3500
4500
Lakewood
Aurora
5500
6000
6500
6900
Morrison
7000
Cherry Hills Village
7500
8000
Greenwood Village
Littleton
Arapahoe
Douglas
INSTREAM BASIN BOUNDARY
TRIBUTARY BASIN BOUNDARY
WATER QUALITY MONITORING STATION
PROPOSED WATER QUALITY MONITORING STATION
1000 SOUTH PLATTE RIVER AT 50TH AVE. AT DENVER, CO
2000 SOUTH PLATTE RIVER AT 19TH ST. AT DENVER, CO
3000 CHERRY CREEK AT WAZEE ST. AT DENVER, CO
3500 LAKEWOOD GULCH AT DENVER, CO
4500 WEIR GULCH AT DENVER, CO
5500 SANDERSON GULCH AT DENVER, CO
6000 SOUTH PLATTE RIVER AT FLORIDA AVE. AT DENVER, CO
6500 HARVARD GULCH AT DENVER, CO
6900 LITTLE DRY CREEK AT ENGLEWOOD, CO
7000 BEAR CREEK MOUTH AT SHERIDAN, CO
7500 BIG DRY CREEK AT ENGLEWOOD, CO
8000 SOUTH PLATTE RIVER AT LITTLETON, CO

Figure I

MAP OF DRURP STUDY AREA SHOWING INSTREAM AND TRIBUTARY BASINS.

PROJECT AREA

B. Instream Sites

I. Catchment Name - South Platte River at 50th Avenue at Denver.

   A. Area - 119,900 acres.

   B. Population - 581,882 persons.

   C. Land Use

      45,628 acres (38%) is Single-Family Residential.

      6,409 acres (5%) is Multi-Family Residential.

      15,403 acres (13%) is Commercial.

      7,181 acres (6%) is Industrial.

      8,725 acres (7%) is Parkland.

      29,846 acres (25%) is Vacant Land.

      6,708 acres (6%) is Agricultural.

II. Catchment Name - South Platte River at 19th Street at Denver.

   A. Area - 108,329 acres.

   B. Population - 464,942 persons.

   C. Land Use

      40,398 (38%) is Single-Family Residential.

      5,299 acres (5%) is Multi-Family Residential.

      13,341 acres (12%) is Commercial.

      5,596 acres (5%) is Industrial.

      7,775 acres (7%) is Parkland.

      29,212 acres (27%) is Vacant Land.

      6,708 acres (6%) is Agricultural.

III. Catchment Name - Cherry Creek at Denver.

   A. Area - 15,817 acres.

   B. Population - 98,397 persons.

   C. Land Use

      4,629 acres (29%) is Single-Family Residential.

      1,929 acres (12%) is Multi-Family Residential.

      2,509 acres (16%) is Commercial.

      772 acres (5%) is Industrial.

      2,314 acres (15%) is Parkland.

      3,664 acres (23%) is Agricultural.

IV. Catchment Name - Lakewood Gulch at Denver

   A. Area - 10,440 acres.

   B. Population - 50,461 persons.

   C. Land Use

      5,070 acres (49%) is Single-Family Residential.

      628 acres (6%) is Multi-Family Residential.

      2,402 acres (23%) is Commercial.

      211 acres (2%) is Industrial.

      457 acres (4%) is Parkland.

      1,672 acres (16%) is Vacant Land.

V. Catchment Name - Weir Gulch at Denver

   A. Area - 4,789 acres.

   B. Population - 36,547 persons.

   C. Land Use

      2,781 acres (58%) is Single-Family Residential.

      321 acres (7%) is Multi-Family Residential.

      455 acres (10%) is Commercial.

      54 acres (1%) is Industrial.

      587 acres (12%) is Parkland.

534 acres (11%) is Vacant Land.

54 acres (1%) is Agricultural.

VI. Catchment Name - Sanderson Gulch at Denver

A. Area - 4,715 acres.

B. Population - 45,116 persons.

C. Land Use

2,947 acres (62%) is Single-Family Residential.

160 acres (3%) is Multi-Family Residential.

590 acres (13%) is Commercial.

107 acres (2%) is Industrial.

322 acres (7%) is Parkland.

589 acres (13%) is Vacant Land.

VII. Catchment Name - Harvard Gulch at Denver

A. Area - 2,833 acres.

B. Population - 21,873 persons.

C. Land Use

1,838 acres (65%) is Single-Family Residential.

192 acres (7%) is Multi-Family Residential.

459 acres (16%) is Commercial.

38 acres (1%) is Industrial.

267 acres (9%) is Parkland.

39 acres (2%) is Vacant Land.

VII. Catchment Name - Bear Creek at Mouth

A. Area - 14,603 acres.

B. Population - 42,534 persons.

C. Land Use

4,444 acres (30%) is Single-Family Residential.

477 acres (3%) is Multi-Family Residential.

1,317 acres (9%) is Commercial.

318 acres (2%) is Industrial.

1,428 acres (10%) is Parkland.

6,507 acres (45%) is Vacant Land.

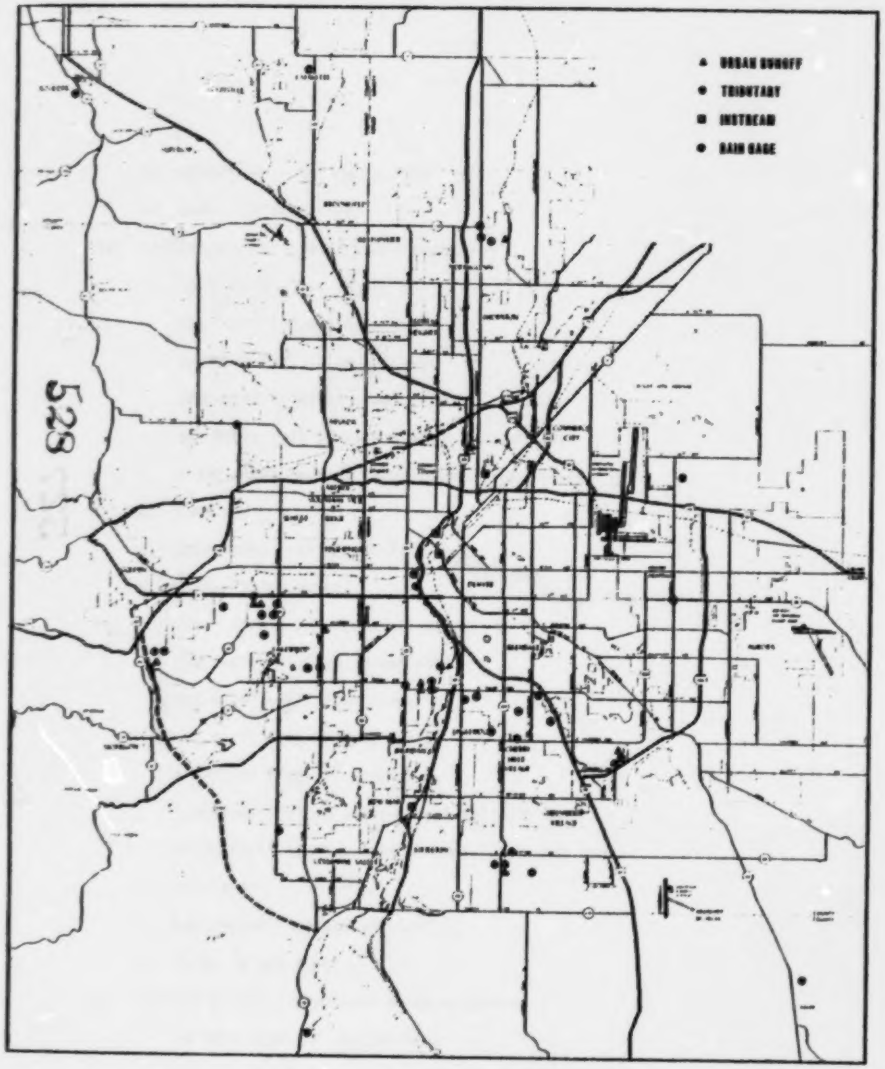
112 acres (1%) is Agricultural.

IX. Catchment Name - South Platle River at Littleton, CO.

This station is the upstream control station.

NOTE: Description of Drainage and Sewerage was not included as it is not applicable for instream sites.

Reproduced from
best available copy.



LOCATIONS OF URBAN, INSTREAM AND TRIBUTARY MONITORING SITES, AND RAINGAUGE NETWORK IN DRURP STUDY AREA.

PROJECT AREA

A. End-of-Pipe Sites

I. Catchment Name - Big Dry Creek Tributary at Easter Street, near Littelton, CO.

- A. Area - 33 acres
- B. Population - 637
- C. Land Use -
  - 33 acres (100%) is Multi-Family Residential
  - 13.6 acres (41.3%) is impervious

II. Catchment Name - Rooney Gulch at Rooney Ranch near Morrison, CO.

- A. Area - 405 acres
- B. Population - 0
- C. Land Use
  - 405 acres (100%) is Open Land
  - 2.43 acres (.6%) is impervious

III. Catchment Name - Asbury Park Storm Drain at Denver (inflow to detention basin)

- A. Area - 121 acres
- B. Population - 1,115
- C. Land Use
  - 104 acres (86%) is Single-Family Residential
  - 16.9 acres (14%) is Commercial

IV. Catchment Name - Asbury Park Storm Drain at Asbury Avenue (outflow to detention basin)

- A. Area - 127 acres
- B. Population - 1,177

C. Land Use

109 acres (86%) is Single-Family Residential

17.8 acres (14%) is Commercial

V. Catchment Name - North Avenue Storm Drain at Denver Federal Center, at Lakewood, CO.
(inflow to detention basin)

A. Area - 68.7 acres

B. Population - 631

C. Land Use

22.7 acres (33%) is Multi-Family Residential

20.6 acres (30%) is Commercial

25.4 acres (37%) is Open Land

VI. Catchment Name - North Avenue Storm Drain at Denver Federal Center North Avenue, at Lakewood, CO.
(outflow to detention basin)

A. Area - 79.7 acres

B. Population - 631

C. Land Use

26.3 acres (33%) is Multi-Family Residential

23.9 acres (30%) is Commercial

29.5 acres (37%) is Open Land

VII. Catchment Name - Cherry Knolls Storm Drain at Denver

A. Area - 57.1 acres

B. Population - 1,388

C. Land Use

57.1 acres (100%) is Multi-Family Residential
21.4 acres (37.5%) is impervious

VIII. Catchment Name - Storm Drain at 116th Avenue and Claude Court, at Northglenn, CO.

A. Area - 167 acres

B. Population - 2,406

C. Land Use

167 acres (100%) is Single Family Residential
39.9 acres (23.9%) is impervious

IX. Catchment Name - Villa Italia Storm Drain at Lakewood, CO

A. Area - 73.5 acres

B. Population - 0

C. Land Use

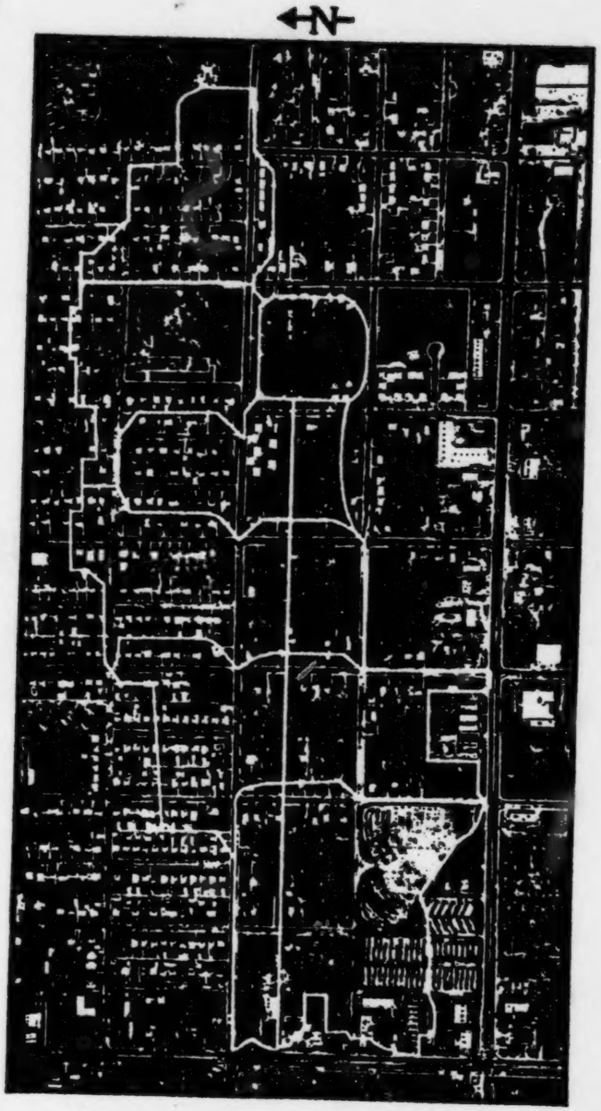
73.5 acres (100%) is Commercial
67 acres (91.2%) is impervious

Note: Drainage and Sewerage information was not provided by project in time to be included in report.

Reproduced from
best available copy.

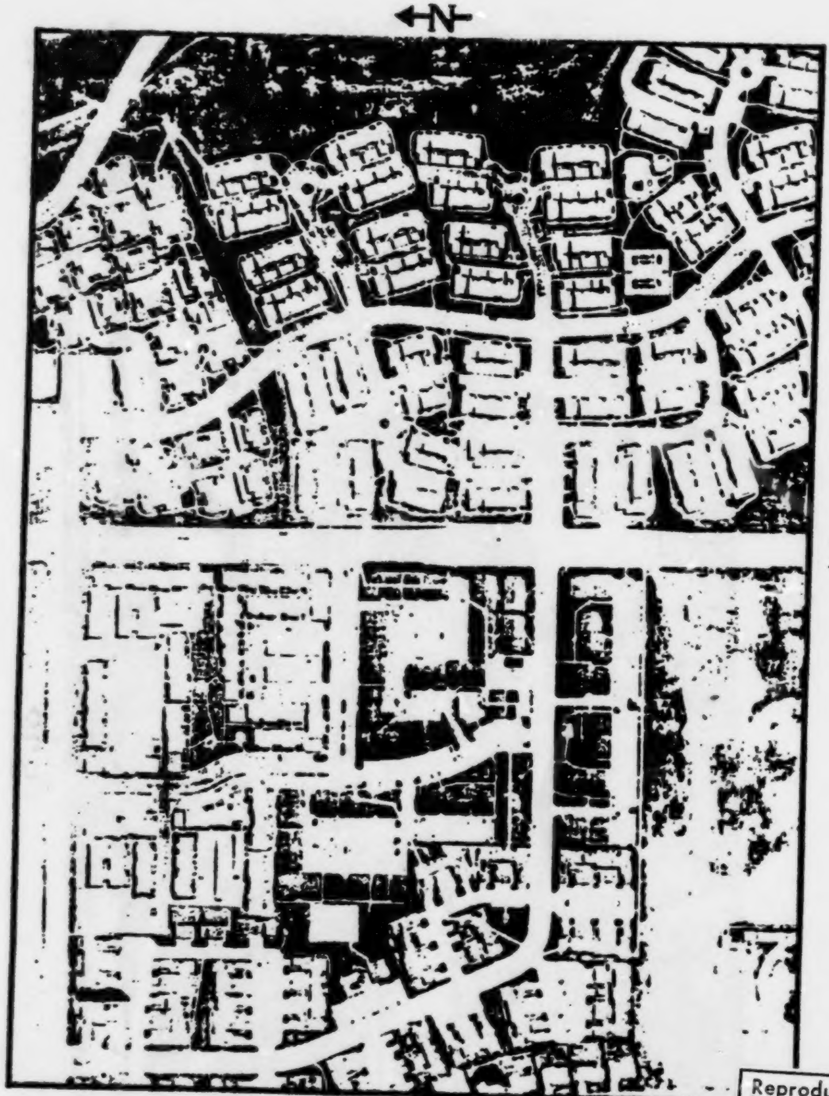
SINGLE FAMILY RESIDENTIAL BASIN AT 116TH AND CLAUDE CT. (NORTHGLENN). AREA = 167 ACRES.

G22-14

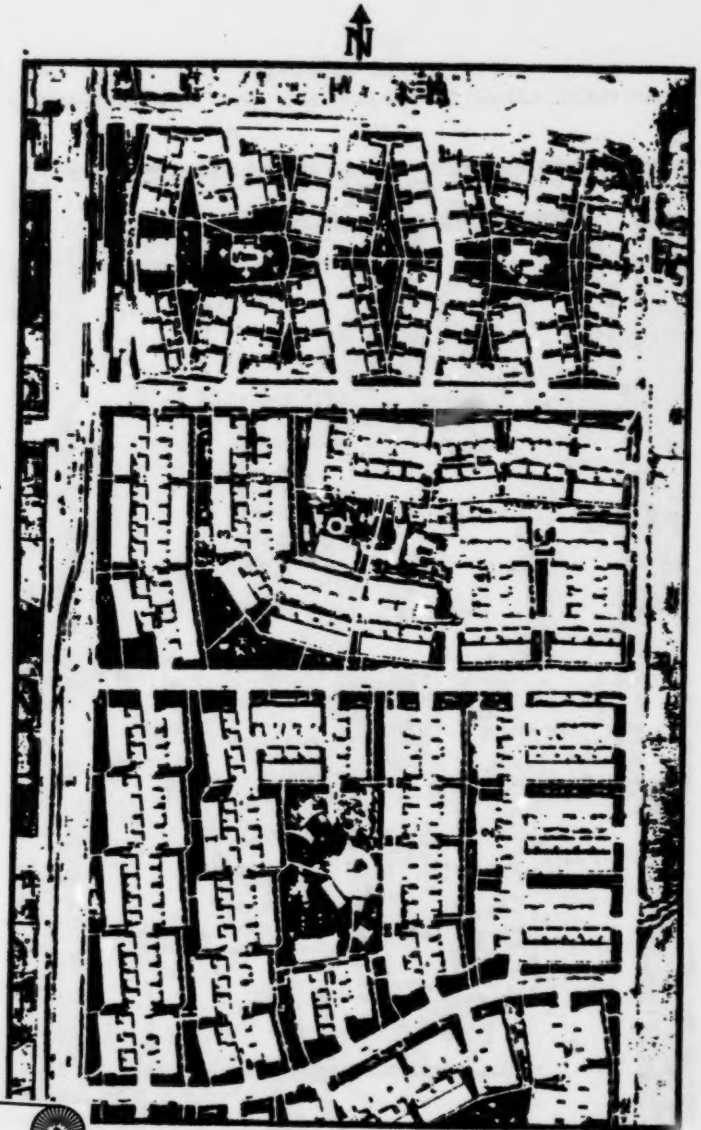


SINGLE FAMILY RESIDENTIAL BASIN AT TEJON ST. (UPPER AND LOWER ASBURY PARK). AREA = 248 ACRES.

G22-15



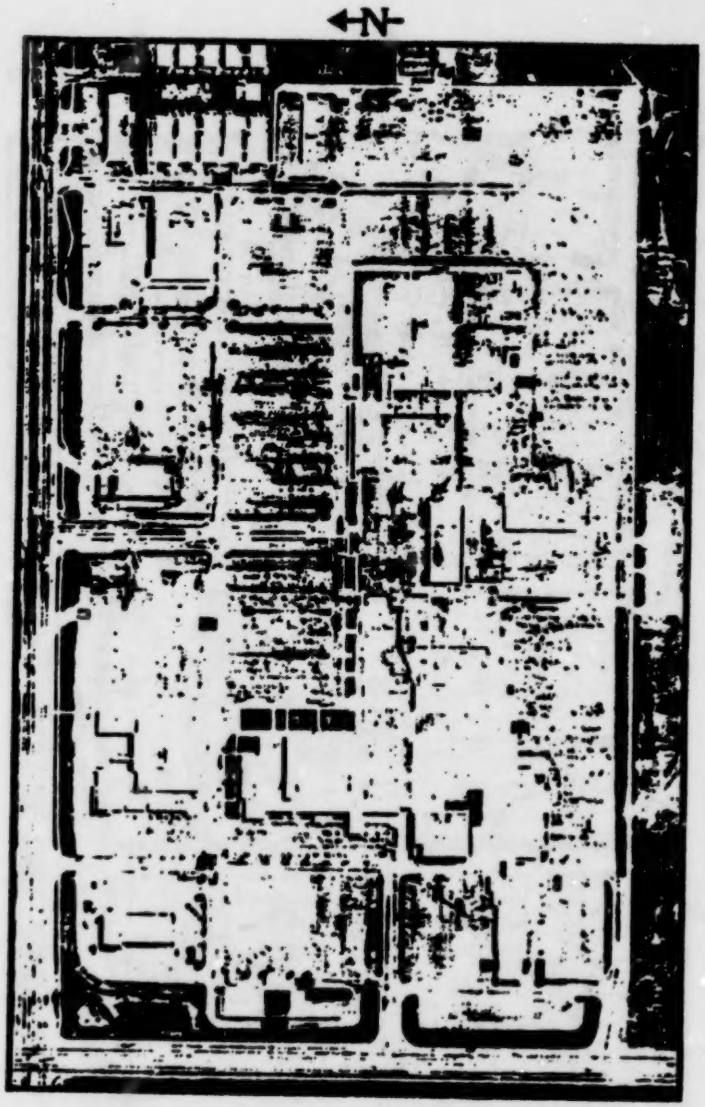
MULTI-FAMILY RESIDENTIAL BASIN AT EASTER ST. (SOUTHGLENN).
AREA = 30 ACRES.
G22-16



Reproduced from
best available copy.

MULTI-FAMILY RESIDENTIAL BASIN AT CHERRY KNOLLS STORM DRAIN.
AREA = 57.1 ACRES.
G22-17

MIXED COMMERCIAL AND RESIDENTIAL BASINS AT NORTH AVENUE STORM DRAIN (UPPER AND LOWER DENVER FEDERAL CENTER).
AREA = 148.4 ACRES. G22-18



COMMERCIAL BASIN AT VILLA ITALIA SHOPPING CENTER STORM DRAIN.
AREA = 73.5 ACRES.
G22-19

NATURAL GRASSLAND BASIN AT ROONEY GULCH. AREA = 405 ACRES.

PROBLEM

A. Local Definition (government)

A report by the Colorado Department of Health has concluded that the major receiving waters in the Denver region are heavily impacted by nonpoint sources of pollution. Bacterial, plant nutrient and heavy metal pollution problems have all been attributed in part to nonpoint sources. The receiving waters have been described by the Health Department as being unsuitable for beneficial uses such as recreation, agriculture and water supply, based upon the 1978 Water Quality Standards of Colorado.

Two flood control and recreational reservoirs, each located on the mainstem of a major Denver area river, are rapidly approaching advance stages of cultural eutrophication. No major point source discharges and little irrigated agriculture presently exist upstream of these two water bodies. Yet, high annual nutrient loads enter these lakes each year, causing accelerated algae productivity evidenced by observed high chlorophyll - A concentrations. It is felt by Denver COG that the nutrient loads originate in large part from nonpoint sources. These watersheds are presently less than 5% developed. Projected land development in one upstream Denver area county alone may result in a population increase of over 4 fold, or 85,000, by the year 2000. It is felt that the increase in runoff volumes resulting from urban development will more than offset the differences in nutrient concentrations in runoff from idle/agricultural lands and the slightly lower values from urban uses.

Results of earlier Denver area nonpoint source pollution studies indicate that large pollutant loads are delivered to area streams from diffuse sources each year. Past studies showed that pollutant loading rates during storm events appear to be within the same order of magnitude as those from point sources. Because of the sparse amount of data available, however, only qualitative assessments of the storm water runoff pollution problems could be made. Before the Denver NURP program it was not possible to quantify the nature of the urban runoff problem.

B. Local Perception (Public Awareness)

The Denver program received funding from many sources - USEPA, Denver Regional Council of Governments, Urban Drainage and Flood Control District, U S Geological Survey and several local jurisdictions.

There is very much interest on the parts of the local governments and citizen groups to gather more information on the extent of the urban runoff problem in Denver.

PROJECT DESCRIPTION

A. Major Objective

The basic objectives of the urban runoff program are to assess the nature, causes, severity and opportunities for the control of urban runoff problems in the Denver region.

The specific principal objectives are:

1) to characterize runoff pollution loadings by land use type
2) identify the specific land surface sources of pollutant
3) determine, to the extent possible, the effect of nonpoint source pollution loads on receiving waters
4) determine the technical and institutional opportunities for the control of nonpoint source loads
5) determine, through computer model calibration efforts, dry weather land surface accumulation rates appropriate for the Denver region.

B. Methodologies

Urban runoff monitoring sites were selected that represent the specific urban land use classifications that generate significant runoff pollution loadings. Land use types selected include single-family residential, multi-family residential, commercial, industrial, parkland and idle/native land. Several sites were also chosen on the South Platte River to monitor the effect of urban runoff on the receiving water. Several detention ponds are being monitored.

The field data collected includes rainfall and runoff at the mouth of each tributary ambient flow at the mouth of each tributary, quality data at tributaries major point sources, instream stations, and irrigation return flows, precitation data for all basins, and weather records.

There are nine urban runoff monitoring sites in seven basins representing discrete land use types. There are eight instream stations being monitored. There are two detention basins being monitored at both the inlet and outlet.

The analysis procedures consist of the following steps:

1) quantify runoff and pollutant concentrations from each of the nine urban runoff sites for selected numbers of quality constituents
2) determine any difference in loadings of pollutants, if any, by land use type. Determine correlation coefficients through linear or non-linear statistical techniques.
3) apportion each tributary basin that has been measured for flow and quality parameters by land use type, % imperviousness, etc.
4) apply conversion factors for each land use type to the total basin area and sum. Compare predicted loads vs. measured loads

5) analyze comparisons for each major constituent in each tributary and determine a correction factor if needed to apply to the larger instream basins
6) apply loading factors to large basins. Compare predicted loads with measured loads
7) evaluate BMP's by using empirical detention pond data as the best estimate of water quality improvement. Apply a factor of pollutant loads vs. detention time to determine gross improvements, if any

There are several special pollution studies being carried out in the following area: characterization of the relationships between total and soluble pollutant loads of several land uses, determination of possible relationships between the fractions of pollutant load associated with discrete particle sizes in the Denver region with those found in studies across the country, and determination of the relationship between flow-proportioned composite sampling and discrete sampling.

C. Monitoring

U. S. Geological Survey is performing the sampling at the runoff sites. The equipment installed at each site consists of Manning automatic water quality samplers, stage recorders, system control units, recording rain gages and wetfall/dryfall samplers. Automatic samples are taken at each site.

At the instream sites, a sample will be taken and composited in the field. The equal transit rate method of depth-and-width-integrating the flow will be the sampling technique. A USDH-59 sampler equipped with teflon nozzles is used to collect the samples. The sampler is lowered into the water at a number of equally spaced intervals marked across the stream. The individual depth integrated sample volumes collected will be placed into an eight liter churn splitter to make up the six liter composite sample volume required.

Water quality sampling of the South Platte is carried out on a weekly basis in the same manner.

Initiation of sampling activities is determined by early storm warning services provided by a private weather service.

D. Controls

Adams County is developing a concise manual that may be utilized by local government planning departments and developers in evaluating and controlling runoff pollution from transitional and newly stabilized urban areas.

To test the feasibility of implementing the control measure requirements at the local government level, Adams County is participating as a prototype for the Model Implementation Program. The purpose of the program is to assess the effectiveness of the nonpoint source pollution ordinance in identifying institutional implementation opportunities and problems.

In addition to this, two detention basins have been instrumented in order to determine the best structural arrangement to control sedimentaion. Samples are collected at both the inlet and outlet of the detention ponds to determine the effectiveness of the control measures.

NATIONWIDE URBAN RUNOFF PROGRAM

SALT LAKE COUNTY DIVISION OF FLOOD CONTROL
AND
WATER QUALITY

SALT LAKE CITY, UTAH

REGION VIII, EPA

INTRODUCTION

The Jordan River is the ultimate receiving water for essentially all urban runoff generated in Salt Lake City. The river is designated as water quality limited for the entire length in the county which means that water quality criteria for designated beneficial uses is not presently being met nor will it be met even with application of stringent effluent limitations for point source discharges.

As discussed in the Salt Lake County Area-Wide Water Quality Management Plan, a principal reason for non-attainment of beneficial uses is the adverse impacts from urban runoff pollution. These impacts are not localized-they occur county wide and because of the complexity of the surface hydrologic system in the county, all urban runoff impacts are transferred from one segment to another. Urban runoff pollution generation in one area causes direct impairment of beneficial uses up to 25 miles away.

The purpose of the Salt Lake County NURP project is to build on this early 208 data base and also to demonstrate the effectiveness of control strategies for mitigation of urban runoff pollution of the surface waters of Salt Lake County.

PHYSICAL DESCRIPTION

A. Area

Salt Lake County is bounded on the east by the Wasatch Mountains, on the West by the Oquirrh Mountains and on the south by the Traverse range. The Great Salt Lake is the final receiving water for the north flowing Jordan River and essentially all waters in the county. Streams originating from the Wasatch Front flow westward into the Jordan River, the only natural outlet from Utah Lake in Utah County to the south. No major streams originate from the western side of the valley. The three mountain ranges along with the Great Salt Lake create a virtually enclosed hydrologic basin in the county.

The elevation of the Great Salt Lake is approximately 4200 feet above mean sea level. The Wasatch Front reaches elevations of over 11,000 feet above sea level while the Oquirrh Mountains to the west reach elevations of over 9200 feet. The land surface between these ranges of mountains consists of a series of benches, each of which slopes gradually from the mountains and drops sharply to the next bench.

The Salt Lake Valley has a maximum length of 31 miles and an approximate width of 23 miles. Roughly 65 percent of the 764-square mile County lies within the valley itself with the remaining 35 percent in the surrounding mountainous areas. Approximately half of the mountainous areas are under the management of the U.S. Forest Service.

Figure 2 summarizes the topography of the basin.

Valley geology is largely a product of ancient Lake Bonneville, which through centuries of rising and falling, carved a linear north-south corridor of steep shorelines and associated shore facies. These facies and lacustrine deposits range from cobbly, well drained formations to sandy, silty formations.

The historic drainage of the Jordan River through the valley floor together with its intercepted mountain tributaries carved several fairly deep chasms through layer-upon-layer of deposited floodplain and alluvial formations.

The Jordan River has formed a massive saline delta at the southeastern end of the Great Salt Lake where it deposits eroded material over a large area referred to as "Salt Marsh."

Geologic formations in the valley significantly influence hydrology, particularly with regard to the movement of subsurface water. Artesian pressure is common along fault scarps throughout the valley with numerous springs providing significant gains to both natural and artificial channels. Artesian pressure is prevalent in the Salt Marsh area where seepage from both confined and unconfined aquifer reservoirs surfaces.

The geologic elements of combined alluvium, talus, and till form a well drained association of highly permeable rocks which provide recharge to the aquifer. Municipal and private wells are common in proximity to this recharge area.

Figure 3 provides a summary of geologic conditions in Salt Lake County.

B. Population

Presently, Salt Lake Valley accomodates about 620,000 people, living in approximately 200,000 homes. These homes occupy a total area of about 37,000 acres.

Since 1847, the population of the County has steadily grown until it now serves the intermountain region as a center of commence, industry, communication, medicine, education and finance.

The past and present figures concerning population and land use are shown below:

Year	1960	1970	1980
Population	383,035	458,607	620,000
Household Size	3.5	3.4	3.1
Occupied Dwelling Units	108,007	134,926	200,000
% Population Increase		19.7	35.2

C. Drainage

The major hydrologic features in Salt Lake County consist of surface water and groundwater systems. Surface systems are comprised of a natural tributary drainage system which is intercepted repeatedly by an irrigation canal system constructed after initial settlement of the valley. Natural segments of major tributaries generally flow east to west to the Jordan River while the canal segments generally flow south to north. Subsurface systems consist of confined, unconfined and perched aquifers recharged in areas along the Wasatch Front.

Figure 4 illustrates the major surface water system components of Salt Lake County. Figure 5 shows the extent of the subsurface hydrological regime.

Jordan River & Tributaries

From Utah Lake, the Jordan River meanders approximately 55 river miles northward to the Great Salt Lake. The river gradient is slight, averaging only 5.2 feet per mile. The river flow is supplemented by tributaries entering the river from the east and groundwater flows depleted during the summer by diversions into irrigation canals.

At the Jordan Narrows, ten miles north of Utah Lake (Salt Lake County-Utah County line) the bulk of the river flow is diverted into irrigation canals during the irrigation season (May-September). Flow immediately below the diversion varies from 1400 cfs during spring runoff to no flow during summer months. North of the diversions, the Jordan River meanders through a broad flood plain, gaining flow from groundwater, irrigation returns, URC, and several small area wastewater treatment plants. The 20-mile reach of the river that passes through the Salt Lake City metropolitan area is the receiving water for a large amount of urban runoff. At 2100 South Street, much of the river flow is diverted into the Surplus Canal. This canal was designed to provide for a direct access to Great Salt Lake for flood control purposes protecting downstream areas on the Jordan River. North of Salt Lake City, the river and Surplus Canal flow into marshland areas that feed the Great Salt Lake.

D. Sewerage System

There are no combined sewers in the Salt Lake study area. The drainage is all through storm sewers and canals.

Reproduced from
best available copy.

Figure I

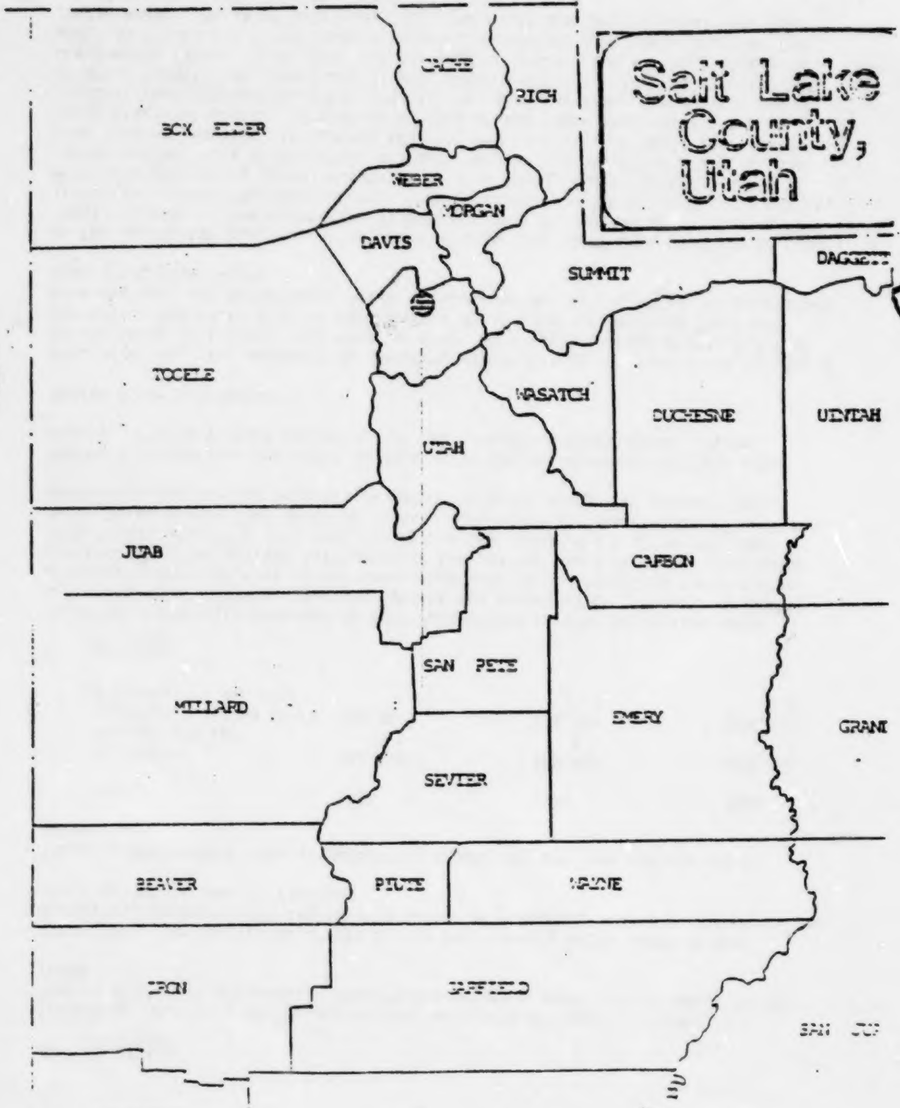
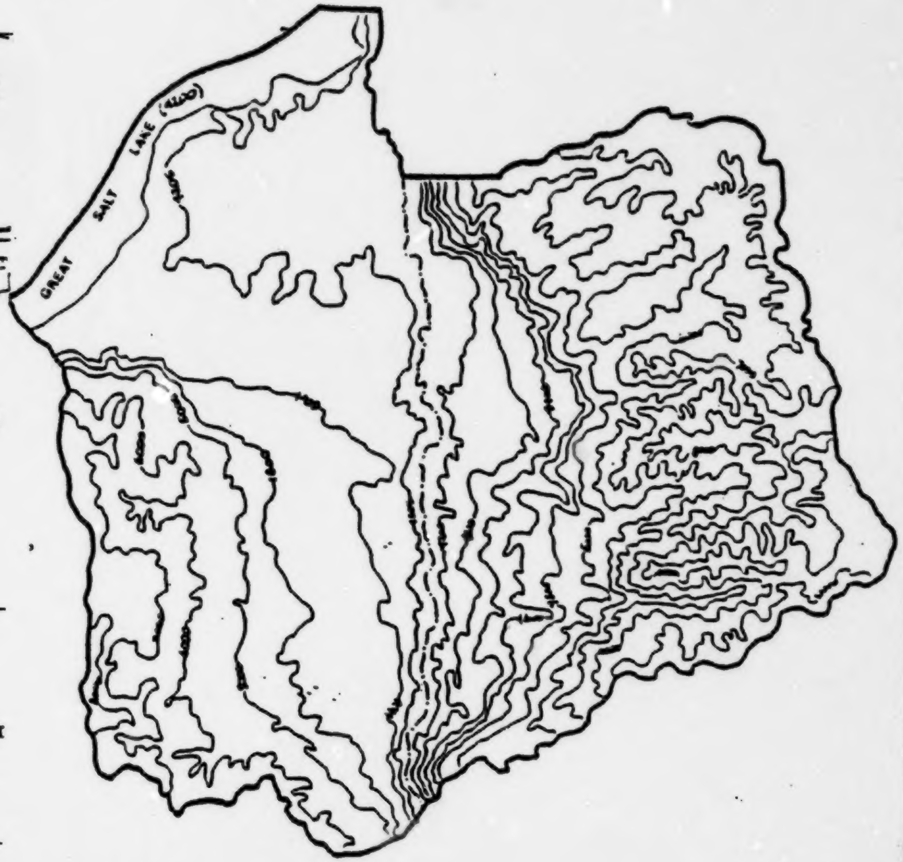


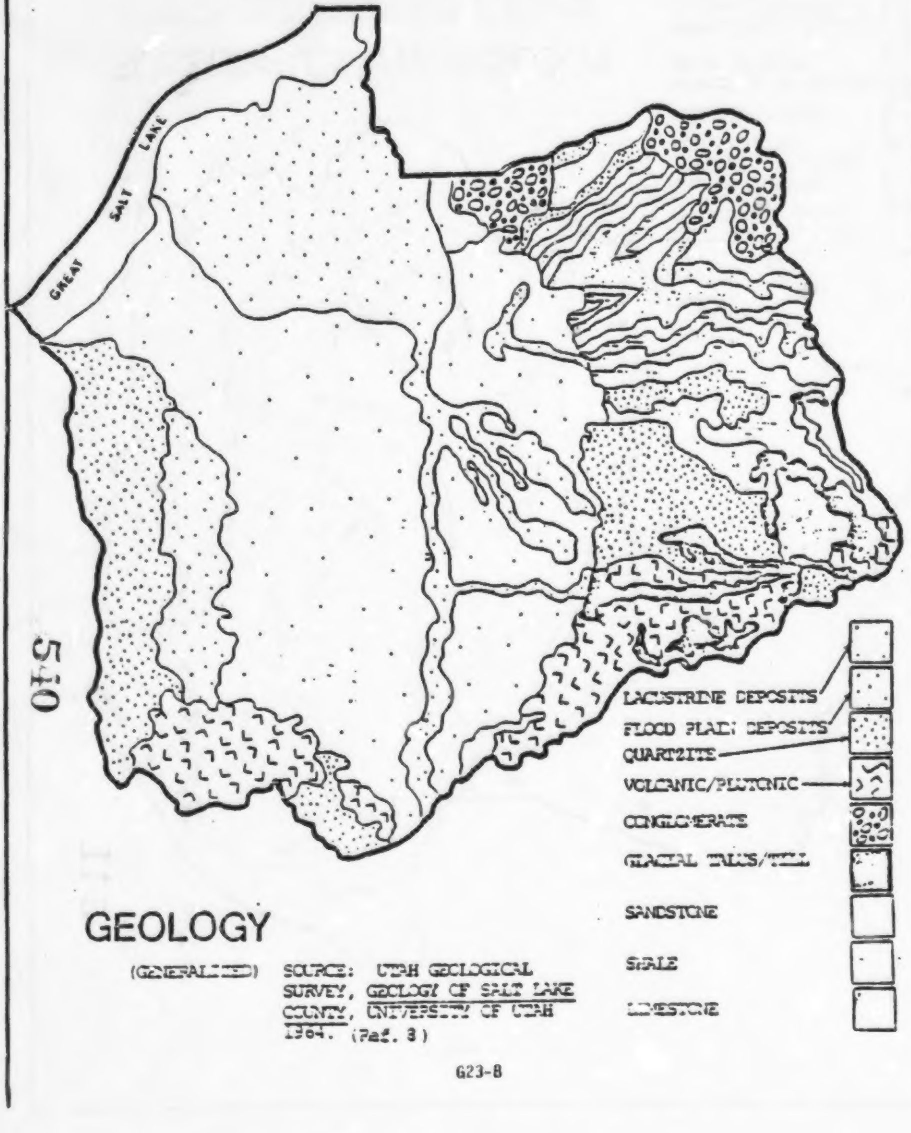
Figure II



TOPOGRAPHY

(GENERALIZED) SOURCE: U. S. GEOLOGICAL SURVEY. TOPOGRAPHIC QUAD SHEET COMPOSITE OF SALT LAKE COUNTY. S.L. CO. 208 Water Quality Project, 1976. (Ref. 7)

Figure III

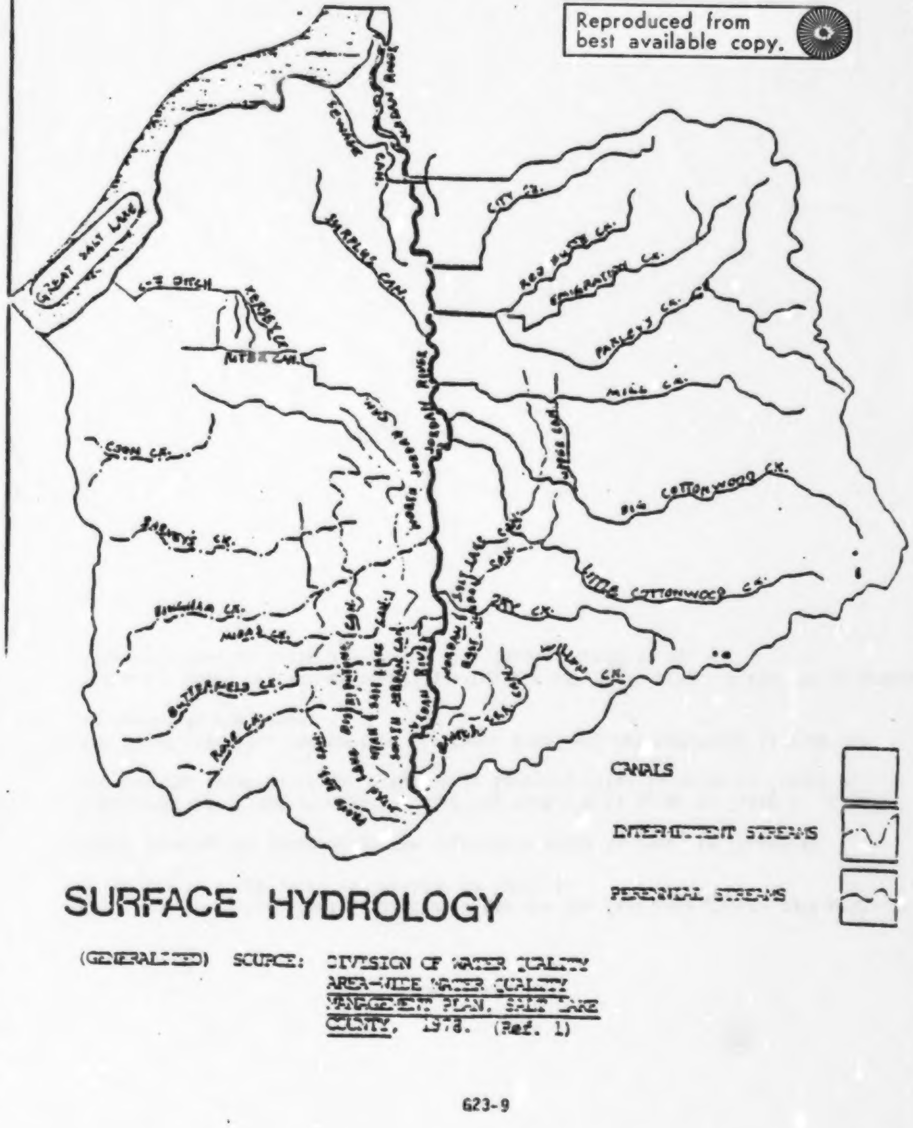


GEOLOGY

(GENERALIZED) SOURCE: UTAH GEOLOGICAL SURVEY, GEOLOGY OF SALT LAKE COUNTY, UNIVERSITY OF UTAH 1964. (Ref. 3)

Figure IV

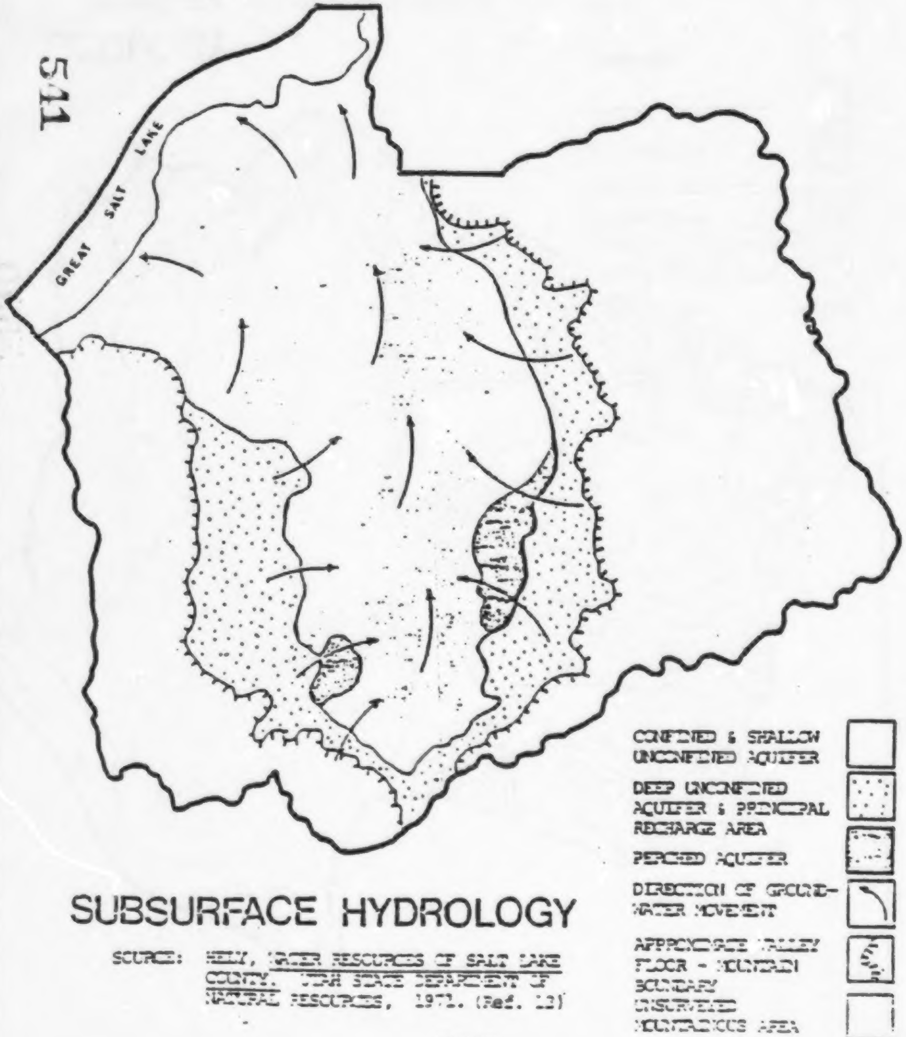
Reproduced from best available copy.



SURFACE HYDROLOGY

(GENERALIZED) SOURCE: DIVISION OF WATER QUALITY AREA-WIDE WATER QUALITY MANAGEMENT PLAN, SALT LAKE COUNTY, 1978. (Ref. 1)

Figure V


GREAT SALT LAKE
CONFINED & SHALLOW UNCONFINED AQUIFER
DEEP UNCONFINED AQUIFER & PRINCIPAL RECHARGE AREA
PERCHED AQUIFER
DIRECTION OF GROUND-WATER MOVEMENT
APPROXIMATE VALLEY FLOOR - MOUNTAIN BOUNDARY
UNSURVEYED MOUNTAINOUS AREA

SUBSURFACE HYDROLOGY

SOURCE: HELY, WATER RESOURCES OF SALT LAKE COUNTY. UTAH STATE DEPARTMENT OF NATURAL RESOURCES, 1971. (Ref. 13)

PROJECT AREA

There are forty-four (44) assessment sites for the Salt Lake County NURP project. A listing of these sites is included on Table 1.

A map showing the location of the assessment sites is shown in Figure VI.

A description of the atmospheric sampling stations is shown on Table 2. A map showing the location of the atmospheric sampling sites is shown in Figure VII.

The fixed site data information for these sites was not submitted in time for inclusion in the Report.

There are eight (8) actual sampling sites for BMP evaluation. A listing of these sites is shown on Table 3. Figure VIII locates these sites.

TABLE 1

ASSESMENT SITES AND TYPE OF SAMPLING

STATION NUMBER	STATION LOCATION	STATION IDENTIFICATION	STATION TYPE
1	East Jordan Canal @ Little Cottonwood Creek (upstream)	10167105	WG
2	East Jordan Canal @ Little Cottonwood Creek (downstream)	10167106	WG
3	East Jordan Canal @ Pump House	10167115	PR
4	East Jordan Canal @ Tanner Ditch	10167118	WG
5	Upper Canal @ Tolcate Lane	10167122	WG, AS
6	Upper Canal @ Holladay Drain		
7	Upper Canal @ Wild Rose Lane	10167125	WG, AS
8	Upper Canal @ Mill Creek (upstream)	10167127	SG
9	Upper Canal @ Mill Creek (downstream)	10167128	SG
10	Jordan & Salt Lake Canal @ Little Cottonwood Creek (upstream)	10167141	WG
11	Jordan & Salt Lake Canal @ Little Cottonwood Creek (downstream)	10167142	WG
12	Jordan & Salt Lake Canal @ Big Cottonwood Creek (upstream)	10167145	WG
13	Jordan & Salt Lake Canal @ Big Cottonwood Creek (downstream)	10167146	WG
14	Jordan & Salt Lake Canal @ Mill Creek (upstream)	10167147	WG
15	Jordan & Salt Lake Canal @ Mill Creek (downstream)	10167148	WG
16	Jordan & Salt Lake Canal @ Zenith Ave.	10167149	CG, AS
17	90th South Conduit @ Jordan River	10167240	WG, AS

TABLE 1

ASSESSMENT SITES AND TYPE OF SAMPLING

STATION NUMBER	STATION LOCATION	STATION IDENTIFICATION	STATION TYPE
18	Little Cottonwood Creek @ Canyon Mouth	10167500	WG
19	Little Cottonwood Creek @ 2050 East	10167700	WG
20	Little Cottonwood Creek @ Jordan River	10168000	WG, AS
21	Big Cottonwood Creek @ Canyon Mouth	10168500	WG
22	Big Cottonwood Creek @ Cottonwood Lane	10168800	WG
23	Holladay Drain @ Big Cottonwood Creek	10168840	CG, AS
24	Big Cottonwood Creek @ Jordan River	10169500	WG, AS
25	Mill Creek @ Canyon Mounth	10170000	WG
26	Mill Creek @ Jordan River	10170250	WG, AS
27	2100 South Conduit @ Jordan River	10170900	CG, AS
28	Parley's Creek @ Canyon Mouth	10171600	WG
29	13th South Conduit @ Jordan River	10171801 Pre-1981 1017235L Post-1981	WG CG, AS
	(SOUTH CONDUIT)		
30	13th South Conduit @ Jordan River	10171802 Pre-1981 10172352 Post-1982	CG, AS
	(NORTH CONDUIT)		
31	Emigration Creek @ Canyon Mouth	10172000	WG
32	Red Butte Creek @ Fort Douglas (below reservoir)	10172220	WG

TABLE 1

ASSESSMENT SITES AND TYPE OF SAMPLING

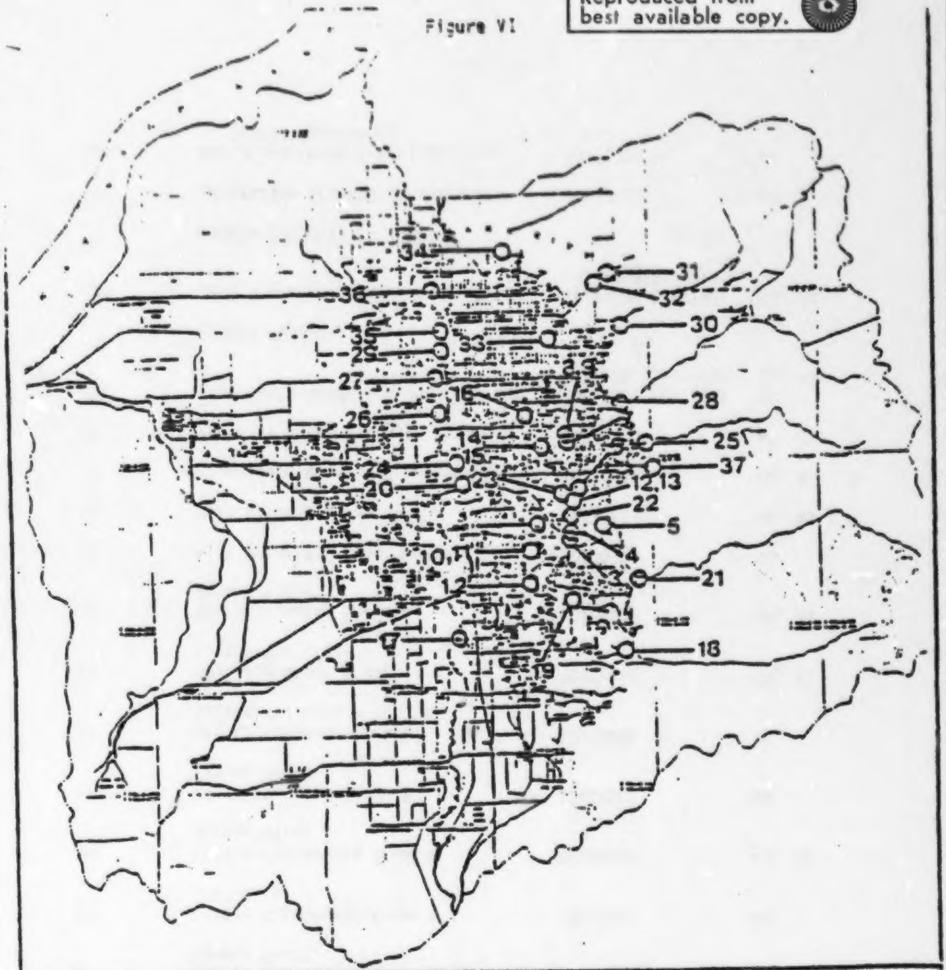
STATION NUMBER	STATION LOCATION	STATION IDENTIFICATION	STATION TYPE
33	City Creek @ Canyon Mouth	10172500	WG
34	8th South Conduit @ Jordan River (SOUTH CONDUIT)	10172511 Pre-1981 10172371 Post-1981	CG, AS
35	8th South Conduit @ Jordan River (MIDDLE CONDUIT)	10172512 Pre-1981 10172372 Post-1981	CG, AS
36	8th South Conduit @ Jordan River (NORTH CONDUIT)	10172513 Pre-1981 10172373 Post-1981	CG, AS
37	North Temple Conduit @ Jordan River	10172520	CG, AS
38	Neff Creek @ Canyon Mouth		SG
39	Jordan River @ Narrows	10167001	WG, AS
40	Jordan River @ 90th South	10167230	WG, AS
41	Jordan River @ 58th South	10167300	WG, AS
42	Jordan River @ 17th South	10171000	WG, AS
43	Jordan River @ 5th North	10172550	WG, AS
44	Decker Lake Outfall	10170350	SG

*STATION TYPE

WG = well gage, recording
PR = pump records, intermittent records
AS = automatic sampler
SG = staff gage, non-recording
CG = conduit gage (Marsh-McBirney type), recording

Reproduced from best available copy.

Figure VI



SALT LAKE COUNTY WATER QUALITY & WATER POLLUTION CONTROL
NATIONAL URBAN RUNOFF PROGRAM

LOCATION OF NURP ASSESSMENT SITES.

Financed under Section 208 of the 1977 Clean Water Act, as amended.

TABLE 2

DESCRIPTION OF ATMOSPHERIC SAMPLING STATIONS

STATION NUMBER	STATION LOCATION	STATION IDENTIFICATION	STATION TYPE
A-1	Dixie Valley Atmospheric	403758111585501	RR, AD (#49)
A-2	Bell Canyon Atmospheric	40330611514201	RR, AD
A-3	Fire Station #7 Atmospheric	40463211551001	RR, AD
A-4	USGS Administration Bldg Atmospheric	404356111562400	RR, AD
A-5	Sandy Public Works Atmospheric	403538111543101	RR, AD
A-6	Fort Douglas Atmospheric	404600111493801	RR, AD
A-7	Liberty Park Atmospheric	404442111523000	RR
A-8	Suburban Sanitary District No. 1 Atmospheric	404220111544300	RR
A-9	Murray Sewage Treatment Plant Atmospheric	404024111541300	RR
A-10	Murray Vine Street Atmospheric	403829111514500	RR
A-11	Salt Lake Airport Atmospheric	404636111572800	RR
A-12	Salt Lake Downtown Atmospheric	404607111530700	RR
A-13	University of Utah Atmospheric	404600111505000	RN
A-14	Eighth South Atmospheric	10172510	RR
A-15	Foothill Post Office Atmospheric	404355111500100	RN
A-16	Salt Lake City #42 Atmospheric	404205111500600	RN
A-17	I-215 @ Mill Creek Atmospheric	404138111474300	RR
A-18	Olympus Cove Atmospheric	404034111463700	RR
A-19	Holladay Drain Atmospheric	10168840	RR (#2)
A-20	I-215 @ 1050 West Atmospheric	403818111551000	RR

TABLE 2

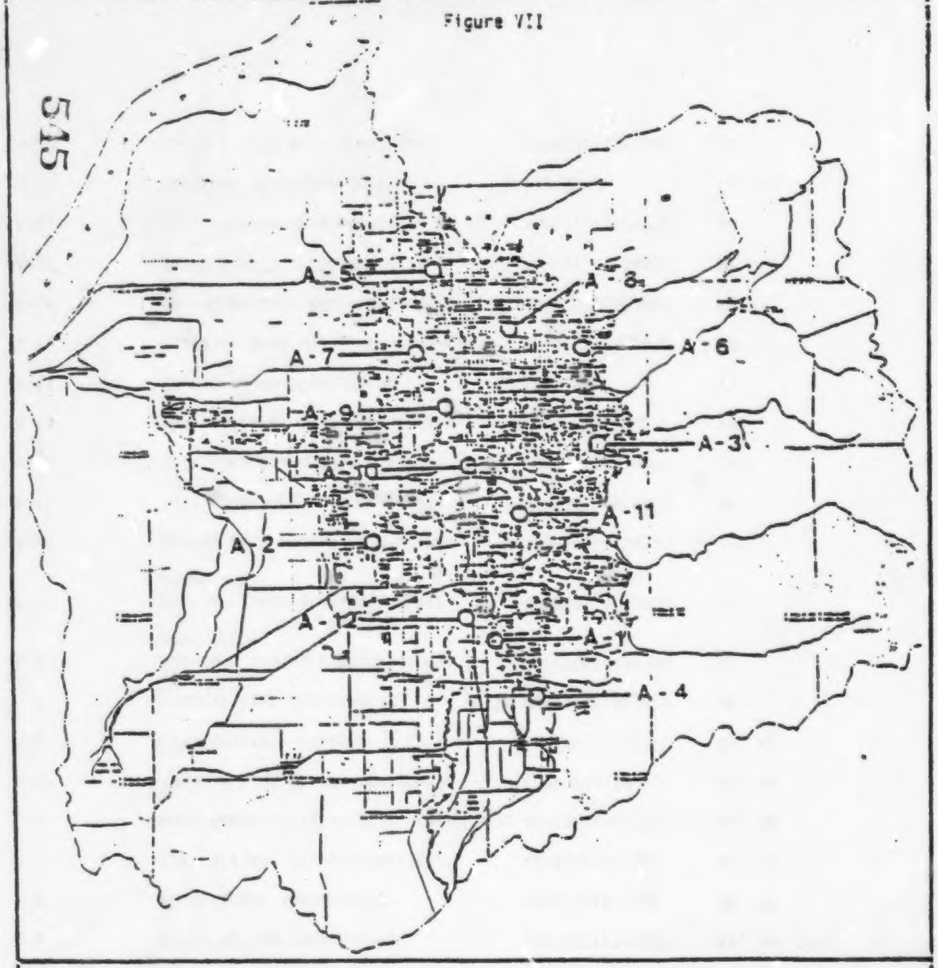
DESCRIPTION OF ATMOSPHERIC SAMPLING STATIONS

STATION NUMBER	STATION LOCATION	STATION IDENTIFICATION	STATION TYPE
A-21	Cottonwood Weir Atmospheric	403708111465800	RN
A-22	Union Atmospheric	403602111510600	RN
A-23	Little Cottonwood Plant Atmospheric	403512111475600	RN

*RR = Rainfall, recording
RN = Rainfall, non-recording
AD = Atmospheric wet-and dry-fall deposition

Reproduced from
best available copy.

Figure VII



SALT LAKE COUNTY WATER QUALITY & WATER POLLUTION CONTROL
NATIONAL URBAN RUNOFF PROGRAM

LOCATION OF ATMOSPHERIC SAMPLING STATIONS.

TABLE 3

SAMPLING SITES AT BMP LOCATIONS

STATION NUMBER	STATION LOCATION	STATION IDENTIFICATION	STATION* TYPE
B-1 **	Overland flow BMP Inlet @ Jordan River (90th South)	10167240	WG, AS
B-2	Overland flow BMP Outlet @ Jordan (Bell Canyon)	10167244	WG, AS
B-3	Public Education/Information BMP (Jackson Comm)	10167220	WG, AS
B-4	Catch Basin Modification BMP (Dixie Valley)	10172552	CG, AS
B-5 to	Detention Basin Modification BMP	-	CG. AS
B-7	(COMBINED INLETS (3) (Dixie Valley)		
B-8	Detention Basin Modification BMP (Outlet)	10167184	CG, AS

*Station Type
WG = well gage, recording
AS = Automatic sampler
CG = Conduit gage, recording (Marsh-McBirney type)

** Also listed as Assessment Site

PROBLEM

A. Local Definition

The Jordan River is the ultimate receiving water for essentially all urban runoff generated in Salt Lake County. The river is designated as water quality limited for the entire length in the county which means that water quality for designated beneficial uses is not presently being met nor will it be met even with application of stringent effluent limitations for point source discharges.

The valley segments of Jordan River tributaries are also designated water quality limited. These stream segments are intermediate receiving waters for urban runoff and could account for the water quality limited designation.

The 208 Area-Wide Water Quality Management Plan states that a principal reason for non-attainment of beneficial uses are the adverse impacts from urban runoff pollution. These impacts are not localized, they occur county-wide. Because of the complexity of the surface hydrologic system in the county, all urban runoff impacts are transferred from one segment to another. Urban runoff pollution generation in one area causes direct impairment of beneficial uses up to 25 miles away.

There are four major sources of urban runoff data in the Salt Lake County area, prior to NURP. The most complete investigation of urban runoff pollution was presented by Jou in 1974 Master's thesis. Four important conclusions from this study are 1) urban runoff from storms has a more detrimental impact on the Jordan River than do daily loads from secondary wastewater treatment plants, 2) BOD and suspended solid concentrations are greater than those from "typical" urban areas, 3) average coliform numbers increase exponentially with population density, and 4) suspended solid loads in Salt Lake City storm sewer discharges are much greater than discharges from San Francisco's combined sewers.

Other studies also showed that urban runoff from the Salt Lake City area contributes to the already high pollutant loads in the Jordan River. Flow values were not recorded in the other studies.

B. Local Perception

The U.S. Geological Survey and the Salt Lake County Public Works Department-Division of Flood Control and Water Quality have taken a big interest in this project. Funds were committed by both agencies in an effort to define the urban runoff problem as well as understand the hydrologic system in Salt Lake County.

PROJECT DESCRIPTION

A. Major Objective

The Salt Lake City NURP program can conceptually be broken down into three phases: problem assessment, control facility design, and control facility evaluation. Problem assessment consisted of monitoring flow and quality of urban runoff, monitoring the Jordan River and irrigation canals. These sites were monitored during dry and wet weather conditions. Additionally, several control facility sites are being monitored for determination of design criteria and evaluation of effectiveness. Atmospheric contribution to urban runoff, both quantity and quality, is being monitored at various stations within and/or adjacent to control facility drainage boundaries. Discharge is continuously monitored at forty stations. Atmospheric quantity is continuously monitored at twenty-three atmospheric sites. Atmospheric quality is monitored on a specific storm basis at six sites. Eight thunderstorm events and including snowfall-snowmelt events were monitored at twenty-eight quality sites (including USGS Jordan River Stations).

Four control strategies were evaluated for effectiveness in abating urban runoff pollution. These BMP's are 1) Modification of existing detention basin, 2) Modification of storm drain catch basins, 3) Public information/education, and 4) Overland flow. Control effectiveness evaluation parameters include reduction in pollutants, cost of control, transferrability to other parts of the county and implementability.

The USGS also has a river quality assessment study ongoing in Salt Lake County. This study is concentrating on groundwater and surface hydrology systems of the county to the extent that they are not duplicated but thay they are in concert with the NURP project.

B. Methodologies

The assessment portion of the project was run for approximately one and one-half years. In addition, low flow winter and summer conditions were monitored for background conditions. A very detailed and complete list of constituents was monitored for as shown below. After initial assessment sampling, a reduced list was agreed upon:

PARAMETER LIST

Particle Size Analysis*
TS*
TDS
TSS
pH
Temperature

COD
Fecal Coliform*
Fecal Streptococcus*
Hardness
Non-Carbonate Hardness

Ca (d)
Mg (d)
Na (d) (%)
SAR
K (d)

Alkalinity
SO_4 (d)
Cl (d)
F (d)
SiO_2 (d)

NO_3 (t) (d)
NO_2 (td)
$NO_2 + NO_3$ (t)
NH_3 (t) (d)
Organic N (d)
N (T)
P (t) (d)
$O\text{-}PO_4$ (d)*

Ba (d)
Be (d)
Cd (tr) (sr) (d)
Cr (tr) (d)
Co (d)
Cu (tr) (d)
Fe (d)
Pb (tr) (d)
Li (d)
Mn (d)
Mo (d)
Ag (tr)
Sr (d)
V (d)
Zn (tr) (sr) (d)

NOTES: * = Not run for all stations and all sample dates. Most of other analyses run for all sites at least for 1/2 the samples collected.

(d) = dissolved
(t) = total
(tr) = total recoverable
(sr) = suspended recoverable

All stream gaging sites were continuously monitored for quantity. All storm drain gaging sites were continuously monitored for quantity and quality to the extent possible.

There are eight actual sampling sites for BMP's. These include the influent and effluent for the overland flow site, 3 influent and 1 effluent sites at a detention basin, a public education BMP, and catchbasin modification, (see Table 3). Following is a brief discussion of each of these sites.

1) Overland Flow - 90th South

This BMP, at the outlet of the 90th South storm drain conduit the Jordan River, will also be monitored for assessment purposes. The concept is to divert runoff onto a spreading area, allow natural processes to treat runoff much the same as in overland flow treatment of wastewater, and to monitor quality of the runoff before discharge to the Jordan River.

Atmospheric contribution of both wet and dryfall quality and quantity is monitored at a location adjacent to the drainage area.

2) Detention Basin Modification - Dixie Valley

The relatively large detention basin located in the Dixie Valley Subdivision in West Jordan City was modified to make essentially all flows pass through the basin. As the basin was designed only flows greater than the capacity of an underground pipe system flowed through the basin. Modification included the blockage of three pipes in the system and forcing runoff up through a grated "bubble-up" box. Monitoring includes quality and quantity instrumentation at three inlets and at one outlet location before discharge to an open ditch. Atmospheric contribution of both wet and dry fall quality and quantity is measured at a location within the basin.

3) Public Education/Information - Bell Canyon

The strategy for this BMP is to monitor runoff quality for two one year periods, one pre-BMP period and one post-BMP period. Atmospheric quantity and quality is monitored at a station located within the basin.

The public education program will mainly take place via personal contact, literature distribution, neighborhood meetings and workshops. These are to be held where intensive information exchange will be the target approach.

4) Catchbasin Modification - Jackson Community

Salt Lake City constructed a drainage system on 900 West Street in the Jackson Community area of the city. Sixteen catchbasins in the system have been designed to include a three foot sump below the flow line of the pipe system. These sumps are filled with sand and capped with asphalt to affect a depth of flow at 0.0 feet below the flow line of the pipe system. After one year of monitoring, the sand and asphalt will be removed, baffles and floatable traps installed, and another one year period of monitoring undertaken. Atmospheric contributions of both wet and dryfall quantity and quality will be monitored by an instrument station near the drainage area.

The results of the BMP analysis will be presented as 1) urban runoff quantity and quality without control, 2) urban runoff quantity and quality after implementation of controls, 3) total and percent reduction of pollutant constituents, 4) costs of implementation of controls, 5) cost per total and percent reduction of pollutant constituents, and 6) cost-effectiveness of each of the controls. The results of the evaluation of control strategies will ultimately be incorporated into an update of the Area-Wide Water Quality Management Plan to be used county-wide.

C. Monitoring

Nineteen of the twenty-eight quality sites are equipped with automatic sampling equipment. These stations have the standard USGS setup which consists of well/float or Marsh-McBirney flow monitors and Manning Samplers. Six Marsh-McBirney units are used in conjunction with 3 System Control Units. Atmospheric stations consist of tipping bucket or weighing bucket rain gages and atmospheric fallout collection buckets if so noted.

BMP evaluation sites are also equipped with Marsh-McBirney or well/float meters, Manning Samplers, System Control Units and rain gages. A control structure for measuring flow is also available at each site. The U.S. Geological Survey is performing the sampling. Discrete samples were taken for the first year of monitoring at the assessment sites. Due to budget constraints it was decided that composite samples would be collected for the remainder of the project.

D. Controls

For a detailed description of the Best Management Practices to be monitored, see Section B.

NATIONWIDE URBAN RUNOFF PROGRAM

SIXTH DISTRICT COUNCIL OF GOVERNMENTS

RAPID CITY, SD

REGION VIII, EPA

INTRODUCTION

Urban runoff from the Rapid City area has been recognized as a problem for many years, and serious quantitative efforts to better define the problem began in 1975. Data have been generated through both the South Dakota School of Mines and Technology and the Sixth District Council of Local Governments.

Past studies in the Rapid City area evaluated the runoff from the Meade St. drainage basin, a developed area which has a contributing drainage area of 1,723 acres. The data showed that the runoff from the watershed contained a high concentration of solids and organic material. According to the data, the runoff from the this one area contributed about half as much COD to the receiving stream during June of 1975 as the continuous effluent from the Rapid City municipal wastewater treatment plant. The city felt that this could be a serious water quality problem considering that Rapid Creek is a high-quality, cold-water trout fishery.

Additional data collected under the 208 work showed that water quality in Rapid Creek met the strict water quality standards for a trout fishery during normal low flow conditions, but the water quality standards are violated during runoff events.

The Rapid City NURP project was proposed to better define the impact of urban discharges and determine if it is necessary to meet in-stream water quality standards during runoff events.

PHYSICAL DESCRIPTION

A. Area

Rapid City is located in Pennington County in western South Dakota, in the center of the Sixth District. It is situated approximately 400 miles north of Denver and 650 miles west of Minneapolis. Rapid City contains the majority of the economic activity of the District. One third of Sixth District's population resides in Rapid City proper.

Rapid City is surrounded by contrasting landforms, with the forested Black Hills rising immediately west of the City and rolling prairies extending out in the other three directions. From 40 to 70 miles southeast lie the eroded Badlands. The Black Hills, many of which are more than 5,000 feet above sea level, with a number of peaks above 7,000 feet, exert a pronounced influence on the climate.

Rapid City experiences wide temperature fluctuations, both daily and seasonal, that are typical of semi-arid continental climates.

Rapid City contains about 18.7 square miles of land of which approximately 67 percent is developed. Development is relatively compact and is generally concentrated east of the ridge running north-south; more recent growth has extended the developed area west of the ridge and also to the southeast. Although there is growth occurring within the City limits, growth adjacent to the City limits is greater.

B. Population

The population of Rapid City was 13,844 persons in 1940. The following two decades were periods of great growth for the City. In 1950, the population was 25,310; and by 1960, it grew to 42,399. During the decade of 1960-1970, population growth rate in the City declined to 3.4 percent, resulting in a population of 43,836 in 1970. A 1973 estimate by the Bureau of Census calculated Rapid City's population to be 47,210. The final 1980 census data shows the Rapid City population to be 46,492.

C. Drainage

Rapid Creek originates within the Black Hills from snowmelt, springs, and forest land runoff. A large reservoir (Pactola) located 20 miles upstream from Rapid City provides flood control and a municipal water supply. Rapid Creek has the characteristics of a relatively large mountain stream, normally flowing at a rapid rate as it meanders over a rocky bottom. There are no known point sources of pollution on Rapid Creek upstream from Rapid City. Activity along the creek, housing developments, construction activities, and storm water discharges all contribute to diminished water quality as the stream progresses.

The Meade Street drainage is one of the major contributors of pollutants to Rapid Creek. The drainage area is in a developed urban area in southeast Rapid City. The Meade Street drainage channel drains more than 20% of the Rapid City area.

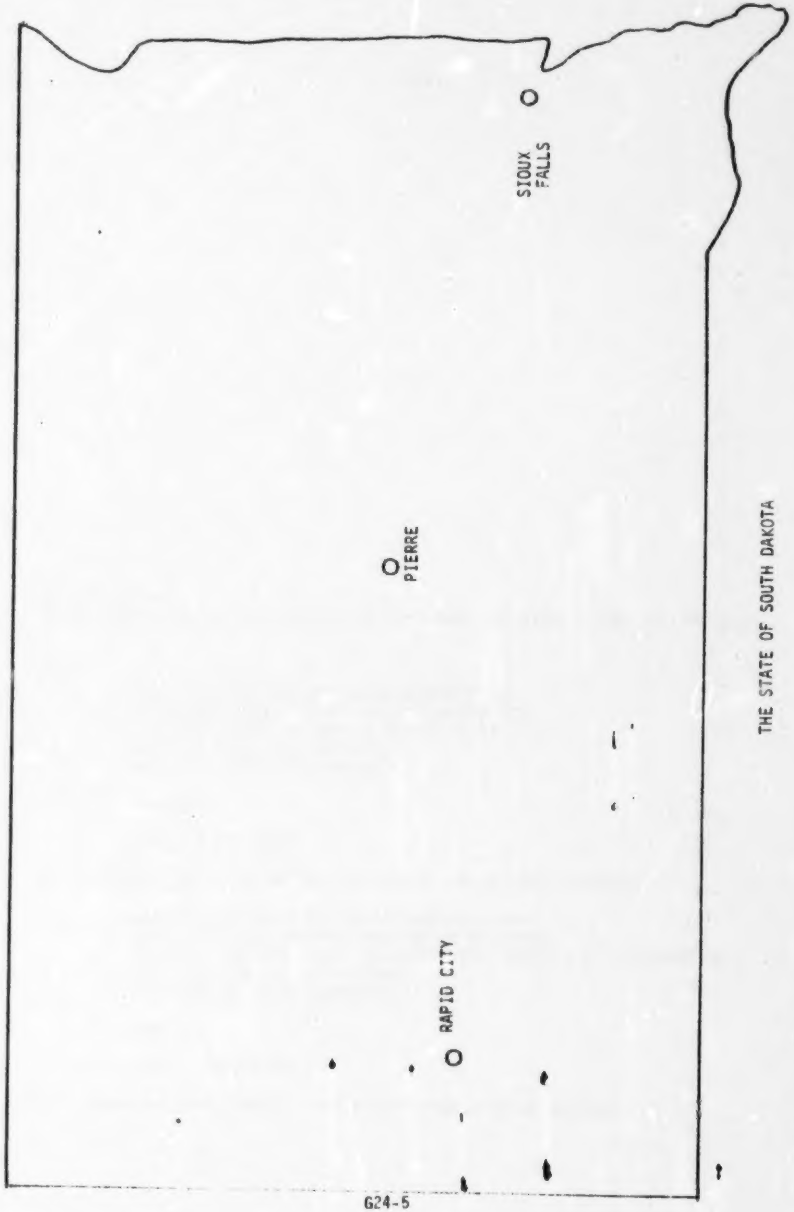
Below Rapid City, extending out onto the prairie, Rapid Creek becomes a more sluggish stream as its slope and velocity decrease. The major point discharge in the area occurs approximately 13 stream miles below Rapid City and consists of treated effluent from the Rapid City Municipal Wastewater Treatment Plant. This plant employs a trickling filter for biological treatment, but does not provide for the removal of phosphorus from the wastewater.

Several non-point discharges occur downstream from agriculture areas and numerous septic systems have been identified adjacent to the Creek.

Extreme variations in flow have been recorded in Rapid Creek. Normal dry weather flows in the summer are of the 20 to 40 cfs magnitude. Runoff events, with flows exceeding 1,000 cfs, can be expected during the study. Flows in excess of 10,000 cfs have been documented.

D. Sewerage

The major system in the urban area of Rapid City is a separate sewer system. There are no combined sewers in the area. In some of the trailer parks outside of town, septic tanks are widely used.



THE STATE OF SOUTH DAKOTA

PROJECT AREA

I. Catchment Name - Rapid Creek above Canyon Lake (06412500)

A. Area - 33,574 acres.

B. Land Use

1,340 acres (4%) is Residential
32,234 acres (96%) is Forest
<.01% is impervious

II. Catchment Name - Rapid Creek above Water Treatment Plant at Rapid City (06413700)

A. Area - 20,877 acres.

B. Land Use

3,340 acres (16%) is Residential
1,043 acres (5%) is urban parkland, open space, institutional, etc.
16,494 acres (85%) is Natural Grassland
1% imperviousness in entire drainage area

III. Catchment Name - Rapid Creek at Rapid Creek, South (06414000)

A. Area - 3,872 acres

B. Land Use

77 acres (2%) is Residential
563 acres (13%) is urban, commercial
194 acres (5%) is Industrial
774 acres (20%) is urban parkland, open space, institutional, etc.
2,324 acres (6%) is Natural Grassland
2% imperviousness in entire drainage area

IV. Catchment Name - Rapid Creek at East Main Street (06414700)

A. Area - 3,540 acres

B. Land Use

1,274 acres (36%) is Residential
496 acres (14%) is Commercial
531 acres (15%) is urban parkland, open space, institutional, etc.
1,239 acres (35%) is Natural Grassland
18% imperviousness in entire drainage area

V. Catchment Name - Rapid Creek below Hawthorn Ditch (0641600)

A. Area - 1,606 acres

B. Land Use

418 acres (26%) is Commercial
321 acres (20%) is Residential
562 acres (35%) is urban parkland, open space, institutional, etc.
305 acres (19%) is Grassland and Agricultural
10% imperviousness in entire drainage area

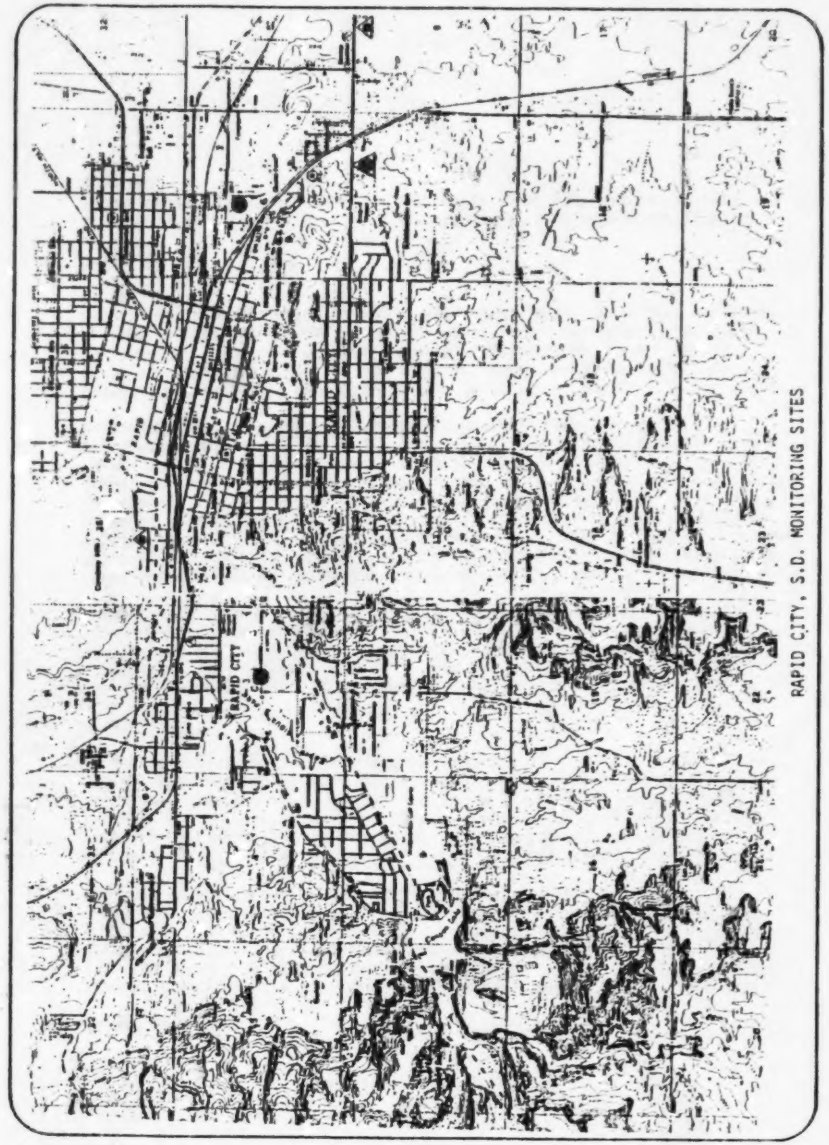
VI. Catchment Name - Meade Street Drain at Rapid City (06416300)

A. Area - 1,760 acres

B. Land Use

968 acres (55%) is Residential
123 acres (7%) is Commercial
423 acres (24%) is Natural Grassland and Forest
246 acres (14%) is Urban Under Construction
19% imperviousness in entire drainage area

Note: The entire fixed site data base was not submitted in time for inclusion in this report.



RAPID CITY, S.D. MONITORING SITES

Reproduced from
best available copy.

PROBLEM

A. Local Definition

From past work done under 208, the Sixth District Council of Governments feels that urban runoff from the Rapid City area into Rapid Creek causes a water pollution problem. The stream water quality standards are not met during storm events. The significance of these standard violations, however, is not clear. Also, the extent that urban runoff affects the trout fishery, the food chain, and species migration is undefined.

The South Dakota Department of Game, Fish and Parks is trying to maintain a trout fishery in Rapid Creek and needs to know the effects of urban runoff. The city of Rapid City is interested in knowing what is now being flushed into the stream. They also need to know what effects, if any, certain structural practices such as metering dams and storm sewer discharges, have with respect to water quality changes. The city is looking for management options for potential implementation measures.

B. Local Perception

The State of South Dakota had recommended that the immersion recreation classification for Rapid Creek be deleted - but that the present fishery classification remain - warm water semi-permanent. The City has requested that the fishery classification be lowered to warm water marginal and the immersion recreation classification be deleted.

Hearings were held on the reclassification which generated much public awareness and interest. A brief history will help clarify the city's interest in the problem.

Rapid Creek is classified as a warm water semi-permanent fish life propagation, immersion recreation, limited contact recreation, irrigation, wildlife propagation and stock watering stream. Since Rapid City received their discharge permit on January 30, 1979, extensive research and evaluation have determined that it will require quite a large expenditure to meet the requirements which exist in the discharge permit. The city is concerned that if millions of dollars are required to meet the discharge permit then measurable benefits should be obtained downstream for the money spent.

The Sixth District Council of Governments is interested in finding out the significance of non-point sources in relation to the point sources (the wastewater treatment plant). Sixth District feels that if they are going to ask the City to clean the wastewater treatment plant to the ultimate degree they better be sure that they are going to have a clean stream afterwards. If non-point sources are a major contributor of pollutants, then maybe a tradeoff could be made.

PROJECT DESCRIPTION

A. Major Objective

From past work under 208 it is felt by the local people that urban runoff from the Rapid City area into Rapid Creek causes a water pollution problem. The stream water quality standards are not met during storm events. The Rapid City NURP project was proposed to better define the impact of urban discharges. The city is interested in knowing if it is necessary to meet in-stream water quality standards during runoff events.

The major objectives of the project are to characterize the impacts of urban runoff into Rapid Creek from rainfall and snowmelt runoff and to evaluate the effects of the runoff on a high quality, cold water fishery. Secondary objectives are to assess the value of in-stream water quality standards as related to water quality during storm events and to assess the impact of urban runoff on downstream beneficial uses.

B. Methodologies

The data collected in the NURP study will undergo analysis by various statistical and modeling techniques. Two levels will be used: regression analysis to determine relationships between a dependent and one or more independent variables, and modeling to determine and define the processes responsible for the volume and characteristics of precipitation runoff.

Three forms of regression analysis will be applied. First, relationships between discrete observations will be observed and correlation coefficients will be developed (ex: ammonia concentration and stream discharge). Second, storm event multiple linear regression will be used to relate storm yields to selected basin and storm characteristics. This will identify the most important independent variables and indicate how they relate to storm yields. Third, long term multiple linear regression will be used to relate annual precipitation to annual loading of Rapid Creek. Regression analysis will be accomplished by using the Statistical Analysis System (SAS).

Detailed modeling will be limited to the Meade Street basin. The two models to be used are 1) Distributed Routing Rainfall-Runoff Model (DR_3M) and 2) DR_3M-QUAL. The DR_3M provides detailed simulation of a storm runoff hydrograph from short time interval rainfall data. DR_3M-QUAL is an urban runoff quality model which is linked with DR_3M. Both models were developed by USGS.

C. Monitoring

Six monitoring stations have been selected, with 5 of them actually being in the creek. Following is a short description of each monitoring site selected:

Station #1	This station is located at the USGS gaging station on Rapid Creek at the west edge of the city. This station was selected as a background water quality station on the creek before significant urbanization occurs.
Station #2	This station is located on Rapid Creek, in the western part of town below some major urban discharges.
Station #3	A station on Rapid Creek near the center of Rapid City. This site will catch all the drainage from western Rapid City plus any drainage from the Cement Plant and limestone quarries.
Station #4	This station is also on the creek and will catch the drainage from both the downtown area and north Rapid City. The stream is a little flatter in this part of town and meanders are more frequent.
Station #5	This station is on Rapid Creek to help determine the stream water quality as Rapid Creek exits the community.
Station #6	This is the only end of pipe site in the project. (Station is located on the Meade Street drainage channel). The Meade Street drainage channel drains over 20 percent of the Rapid City land area.

See the enclosed map for location of these sites.

Stations 1, 3, 5 and 6 are fully equipped with automatic flow measuring and sampling equipment. Stations 2 and 4 have flow measuring devices but manual sampling will be done. At the stations with automatic sampling equipment, the standard USGS setup is used. This setup includes a System Control Unit which controls the functioning of the system and processes data received from rain gages, stage sensor and pump sampler, a digital recorder, a Manning water sampler, and a freezer for cooling samples.

Atmospheric deposition samples will be collected at two sites using Aerochem Metrics Model 301 samplers.

Water quality samples will be composited according to flow and sent to the lab for anlaysis.

D. Controls

Best Management Practices may be evaluated but this will not be done until later on in the project.

NATIONWIDE URBAN RUNOFF PROGRAM

CASTRO, CALIFORNIA

REGION IX, EPA

INTRODUCTION

The San Francisco Bay-Delta Estuary is the single most important water body in the State of California. More than one-half of all of California's fishery resources either live in or directly depend on the Bay Delta Estuary for their survival. San Francisco Bay also provides scenic beauty and recreation to over 5 million people who live near its shore (California State Water Resources Control Board, 1980).

San Francisco Bay is the dominant feature and primary receiving water of the Bay-Delta system. Assessment of the water quality impact on San Francisco Bay from stormwater runoff is difficult because of the drainage from its vast tributary area. The Bay-Delta system receives runoff from about 40% of the land area of California, or about 63,000 sq. mi. About 3200 sq. mi. of the region drains directly to San Francisco Bay.

Castro Valley Creek and many other Bay Area creeks with similar flow volumes can be considered "urban feeder creeks". These may be characterized as having low summer flows and large winter flow variations and providing some natural habitats. It probably is not economically feasible to improve these creeks to a fishable/swimmable status.

Castro Valley, the study area for this project, is a small watershed considered typical of residential basins in the San Francisco Bay Delta Region (Sylvester, 1978). The U.S. Geological Survey and the Corps of Engineers (which initially began monitoring runoff in Castro Valley in 1971) considered Castro Valley a typical residential basin because of the general geology, soils, topography, hydrology, climate, vegetation and human activities in the basin. Assessment of the impact from stormwater runoff on the water quality of Castro Valley Creek shows that the runoff water quality commonly fails to meet beneficial use criteria for several toxic heavy metals.

Although it was beyond the scope of this project to investigate the effects of street cleaning on Bay water quality, the project was based on the assumption that, if street cleaning would improve water quality in Castro Valley Creek, then street cleaning on a larger scale may improve water quality in the Bay.

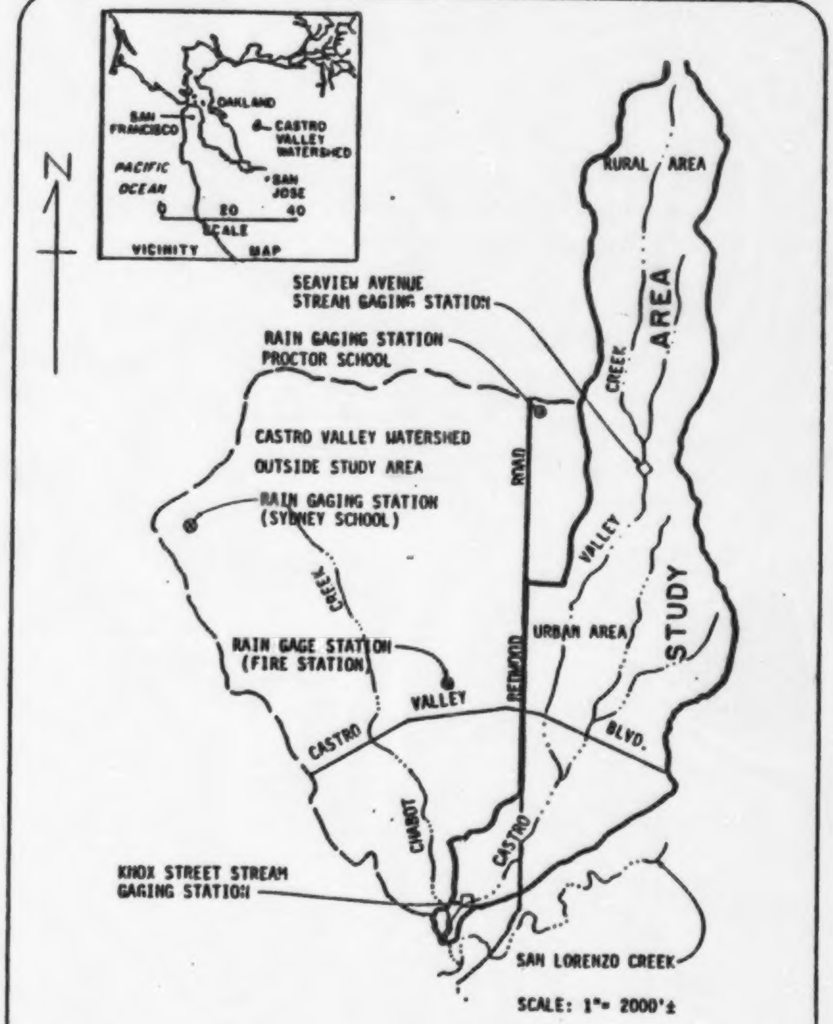

N
SAN FRANCISCO
OAKLAND
CASTRO VALLEY WATERSHED
PACIFIC OCEAN
SAN JOSE
0
20
40
SCALE
VICINITY MAP
SEAVIEW AVENUE STREAM GAGING STATION
RAIN GAGING STATION PROCTOR SCHOOL
CASTRO VALLEY WATERSHED OUTSIDE STUDY AREA
RAIN GAGING STATION (SYDNEY SCHOOL)
RAIN GAGE STATION (FIRE STATION)
KNOX STREET STREAM GAGING STATION
SAN LORENZO CREEK
SCALE: 1"= 2000'±
RURAL AREA
CREEK
AREA
STUDY
VALLEY
URBAN AREA
ROAD
REDWOOD
CREEK
VALLEY
CASTRO
BLVD.
CHABOT
CASTRO

FIGURE 1 - STATE LOCUS, PROJECT AREA AND SAMPLING SITES FOR CASTRO VALLEY NURP PROJECT

PHYSICAL DESCRIPTION

A. Area

Castro Valley is an unincorporated community within Alameda County. The project's study area was a 2.4 sq. mi. portion of this unincorporated area. The Castro Valley Creek branch of the Castro Valley Watershed was selected as the study area because it was a manageable size.

The study area is 1,542 acres and is predominantly residential, with urban, suburban and rural terrain in the flats and hills bordering San Francisco Bay south of Oakland and north of San Jose. The uppermost portion of the study area is rural with about 633 acres of grass and woodlands that is slowly being replaced by suburban development. The Seaview station monitors water quality and quantity from this essentially rural area. Below this station is the urban test area of about 909 acres. Length of the main creek channel between the rural station (Seaview) and the urban station (Knox) is 2.4 miles.

The majority of the residential land use in the urban area consists of single family housing with lot sizes varying from 5,000 square feet to 10,000 square feet. Residential land use of the 909-acre urban study area occupies about 636 acres (70 percent), commercial land use occupies about 64 acres (7 percent), and the remaining land is about 209 acres (23 percent) of open space and institutional land use. Development along the stream banks in Castro Valley is intense and houses are frequently constructed directly over the existing streambed. Some light commercial areas, more than six schools, and a short portion of Interstate Highway 580 are also in the area.

B. Population

Present population is estimated to be 15,000, located principally in the urban area of the watershed, but population in the upper rural area is steadily increasing.

C. Drainage

Topography within the drainage basin is highly variable, and the land slopes range from 10 percent to 70 percent in the upper end of the basin to slopes as low as 1 percent in the valley portion near San Lorenzo Creek. The Castro Valley Creek streambed in the lower portions of the drainage basin ranges from 20 to 50 feet in width and 8 feet to 10 feet in depth. The streambed is often strewn with litter and debris.

Most of the streets in the urban area are asphalt and in fair condition. The gutters are mainly concrete, and the curbs are mostly vertical (rather than rolled).

D. Sewerage System

100% of the drainage area is served by separate storm sewers.

PROBLEM

A. Local Definition (Government)

As a result of P.L. 92-500, many regions of the nation undertook areawide planning studies (supported by 208 grants) to identify and define existing water quality problems. In the Bay Area, the problems investigated included fish kills, shellfish contamination, toxic pollutants, eutrophication, dredging and disposal, oil and chemical spills, and freshwater outflow from the Sacramento-San Joaquin Delta.

The following is a brief description of three of those problems and their probable causes in the San Francisco Bay Area:

- Shellfish beds are widespread, well-populated, and represent a presently under-utilized resource in San Francisco Bay. Commercial and recreational shellfish harvesting is prohibited because of contamination by bacteria, viruses and, in some cases, heavy metals. Storm runoff, sewage discharge and waste from boats are sources of contamination (Association of Bay Area Governments (ABAG), 1978.)

- Many fish kill incidents can be traced to specific pollution causes; however, the fish kills occur in the Bay for unknown reasons. The State is investigating the causes of death of striped bass and has also initiated a study of the aquatic habitat of the Bay.

- There is evidence that the Bay's aquatic life may be adversely affected by toxic materials, e.g., heavy metals, pesticides and organic compounds, which are showing up in analyses of Bay waters. The evidence points to pollutants that occur at low concentrations whose effects are cumulative and/or long-term (ABAG, 1978).

The primary use of many creeks in the Bay area is to convey stormwater runoff into San Francisco Bay. Although runoff contains large amounts of pollutants, its relationship to observed water quality problems in San Francisco Bay remains uncertain. However, Castro Valley Creek's contribution of large quantities of toxic pollutants into San Francisco Bay is seen as a significant water quality problem.

B. Local Perception (Public Awareness)

Because the primary use of Castro Valley Creek is to convey stormwater runoff into San Francisco Bay, public concern for the water quality of the Creek itself is not high. To the extent that it exists, public perception of a water quality problem focuses on the Bay as a scenic, recreational and commercial water resource for all communities within the Bay area. There is widespread and at times vocal citizen concern over Bay water quality. The Bay area 208 Study drew heavily upon public support and active citizen participation in carrying out its problem identification and prioritization tasks. However, the magnitude and technical/institutional complexity of Bay water quality problems tend to discourage remedial action by any one community.

PROJECT DESCRIPTION

A. Major Objectives

The Castro Valley study was directed towards developing information on three subjects which were of particular concern to local decision makers. The objectives were to:

- demonstrate the effectiveness of street cleaning in improving water quality;
- provide information to local Public Works agencies on how to incorporate water quality as a factor into their street cleaning programs; and
- investigate the quantities of asbestos on urban streets and in urban runoff.

Again, the primary purpose of the project was to demonstrate whether removing the pollution load from the street surfaces by street cleaning has an effect on the quality of runoff from street surfaces. The project collected data to compare the monitored mass pollutant flows of the storms with the total pollutant removal of street cleaning programs. The project also investigated a related subject: comparison of the performance of regenerative air (RA) and mechanical street cleaning equipment.

B. Methodology

Project field activities began in October, 1978, and ended in April, 1980. In order to demonstrate the relationship between street cleaning and runoff water quality, the project measured:

(1) street cleaning effectiveness, to identify the quantity of pollutants removed and the initial and residual loadings before and after cleaning for a variety of street cleaning programs; (The street surface particulate sample was obtained by vacuuming portions of the street surfaces immediately before and after the area was cleaned. The two loadings were then compared to obtain measures of street cleaning effectiveness. These samples were then divided into eight discrete particle sizes, weighed, and finally composited over selected time periods by particle size and test area for chemical analyses.)

(2) street surface pollutant accumulation rates to identify the loading on the street at any time;

(3) precipitation, to know the quantity of rainfall; and

(4) runoff water quantity and quality, to identify the quantity of pollutants washed off the watershed for various types of rainstorms. Two monitoring stations were located on Castro Valley Creek. The upper station (Seaview) measured the runoff from the rural area, and the lower station (Knox) measured the runoff from both the urban area and the rural area. The contribution from only the urban test area was determined by subtracting the contribution of the rural station from that of the urban station.

Curve fitting analysis was used to correlate street surface pollutant loadings before rain events with changes in runoff water mass yields.

C. Monitoring

The Alameda County Flood Control District entered into an agreement with the United States Geological Survey to establish two water quality monitoring stations on Castro Valley Creek. The USGS was responsible for gathering flow and stage data and developing a rating curve for these stations. The Alameda County Flood Control District was responsible for collection of samples for chemical parameters and measurement of field parameters. The samples were sent to the USGS Laboratory in Denver, Colorado, for analysis.

The watershed has two distinct parts - the urban and non-urban areas. The rural area's contributions of sediments and pollutants were subtracted from the rest of the watershed to give an accurate accounting of pollutant and sediment loading in the urban study area. To accomplish this, a gaging and water quality monitoring station was established on Castro Valley Creek near the intersections of Seaview Avenue and Madison Avenue, the boundary line between the urban and rural areas of the watershed. Another gaging and monitoring station was established near the intersection of Knox Street and North 4th Street. This station was at the lower end of the watershed and measured the total flow and total pollutant loading of the watershed. In this way it was possible to separate the contributions of each portion of the watershed. Separation was critical since the study was concerned with the urban area.

Three rain gages were used to monitor precipitation in the project area (Figure 1). One was located near the intersection of Redwood Road and Proctor Road at Proctor School. This gage measured the rainfall in the upper watershed. Another was located at the Sydney School outside the study area and was used as a check against the Proctor gage. The third one was located at the Castro Valley Fire Station on San Miguel Avenue in central Castro Valley. From these stations, the rainfall record correlated well with the water quality and street surface data collected during the project.

For the street surface particulate sampling portion of the study, each subsample included all of the street surface materials that would be removed during a severe rain (including loose materials and caked-on mud in the gutter and street areas). The location of the subsample strip was carefully selected to ensure that it had no unusual loading conditions. For example, a subsample was not collected through the middle of a pile of leaves, but where the leaves were lying on the street in their normal distribution pattern. When possible, wet areas were also avoided. If a sample were wet and the particles caked around the intake nozzle, the caked mud from the gobbler was carefully scraped into the vacuum hose while the vacuum units were running at the end of the sampling period.

Each subsample was collected in a narrow strip about 6 in. wide (the width of the gobbler) from one side of the street to the other (curb to curb). In heavily traveled streets where traffic was a problem, some subsamples consisted of two separate one-half street strips (curb to crown). On busy roadways with no parking and good street surfaces, most particulates were found within a few feet of the curb, and a good subsample was collected by vacuuming two adjacent strips from the curb as far into the traffic lanes as possible. Subsamples taken in areas of heavy parking were collected between vehicles along the curbs. Subsamples were collected, composited and submitted to a laboratory for chemical analysis.

To carry out the street cleaning task, several frequencies were evaluated during the first project year. The second project year, however, used a constant street cleaning frequency of 5 times per week for one month followed by two months with no street cleaning operations at all. This enabled the streets to become as dirty as they were likely to become during the first month and then remain at that level during the second month of no cleaning.

Equipment

At both runoff monitoring sites, stream level was monitored by a manometer-servo water level sensor and recorded on a Stevens digital tape recorder. The water quality samples were taken by a modified ISCO automatic wastewater sampler initiated by a continuous-recording modified ISCO Flowmeter with printer. The limited capacity of the samplers' sample holders was expanded during the record year by placing samplers on top of 55-gallon stainless steel drums. This allowed project personnel to monitor completely even the storms of longest duration. All of the water quality sampling equipment was powered by a 90 amp hr. 12 volt car battery. Field parameters were measured by an EXTECH ph meter and a YSI conductivity meter with thermometer.

For the collection of street surface particulate samples, a light-duty (half-ton capacity) trailer was used to carry the generator, tools, fire extinguisher, vacuum hose and wand, and two wet-dry vacuum units. A truck with a suitable hitch and signal light connections was used to pull the trailer. Two-horsepower (hp) industrial vacuum cleaners with one secondary filter and a primary dacron filter bag were selected. The vacuum units were heavy duty and made of stainless steel to prevent contamination of the samples. Both 2-hp vacuums were used together by using a wye connector. This combination extended the useful length of the 1.5-inch vacuum hose to 35 feet and increased the suction so that it was adequate to remove all particles of interest. A wand and gobbler (triangular in shape and about 6 inches across) are also needed. The generator which was used produced about 5000 watts of electrical power.

Most of the street cleaning tests were conducted using a modern, mechanical, four-wheel brush-type street cleaner that had dual gasoline engines and hydraulic controls. The speed during the cleaning program was about five to eight m.p.h. Broom replacement and other maintenance were conducted on a scheduled basis. Operating conditions were held constant during the study program and were not varied. A regenerative air street cleaner was tested for part of the project period and its performance compared with that of the conventional mechanical cleaner in order to provide information to public works officials concerned about replacing their street cleaners. Too little performance difference was observed under the test conditions to justify purchase of one type versus others.

Controls

Project results showed that, when the streets were dirtiest (initial loadings of about 1000 or more pounds per curb mile), the cleaning efficiency was about 40%. Even though the range of percentage removal values varies appreciably, the residual (after street cleaning) loading values were no lower than about 200 pounds per curb mile, even with very intensive cleaning.

After about two or three passes per week, there is very little improvement in either initial or residual street surface loadings. Under these cases, the streets are about as clean as they are likely to get by street cleaning operations and any more frequent street cleaning is unproductive. It is much more cost effective to decrease the street cleaning effort in areas having frequent cleaning and to increase street cleaning efforts in areas with appreciably dirtier streets such as industrial areas.

When the urban runoff yield information was compared to the specific street surface initial loading values for each constituent, this analysis showed that a maximum of about 20 percent of the total solids and about 35 percent of the lead could have been prevented from reaching the receiving water. If maximum urban runoff improvements are going to be realized by street cleaning, then the streets should be cleaned during the winter months between adjacent storm periods. As expected, lead shows the greatest potential for control by street cleaning equipment, followed by total solids and then arsenic. Figure 2 illustrates this relationship and further shows that after about three passes per week, any more street cleaning is unproductive.

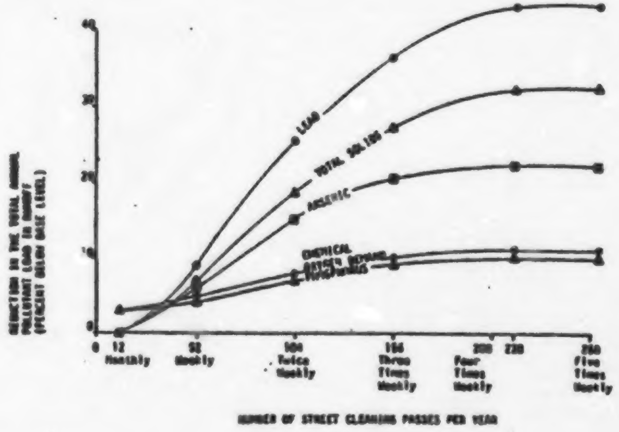


FIGURE 2 - IMPROVEMENT IN URBAN RUNOFF QUALITY AS A FUNCTION OF STREET CLEANING EFFORT.

Results of the special asbestos study yielded some interesting results. In this case current optical techniques provided inadequate to identify asbestos in small quantities, especially for small fiber sizes. About 10% of the runoff which was monitored had detectable asbestos. The annual average asbestos fiber concentration in urban runoff in Castro Valley was about thirty million fibers per liter. This concentration is roughly equivalent to 3×10^{13} fibers per acre per year for an area without any known asbestos in the natural soils. Eighty per cent (80%) of the street surface samples contained detectable asbestos fibers. Street cleaning was found capable of achieving 10% removal of asbestos during weekly street cleaning and up to 50% removal when street cleaning was carried out three times per week.

NATIONWIDE URBAN RUNOFF PROGRAM
FRESNO, CALIFORNIA
REGION IX, EPA

(To Be Provided)

NATIONWIDE URBAN RUNOFF PROGRAM
BELLEVUE, WASHINGTON
REGION X, EPA

BELLEVUE, WASHINGTON

INTRODUCTION

One of the most significant outgrowths of the P.L. 92-500 "208 Water Quality Planning" effort was the recognition of urban storm water quality as a principal contributor to water quality problems in communities throughout the country. Local government agencies have long been involved in the management of urban storm water for the purposes of flow control (quantity) to relieve and reduce local flooding, property damage, and public hazard and inconvenience. A variety of jurisdictional entities have developed throughout the country to perform this function at a local level, including flood control districts, drainage districts, diking districts, soil conservation districts and municipal and regional flood control management departments and agencies. Until recently, however, only a few of these jurisdictions have involved themselves in water quality pursuits as well. Most 208 Water Quality Management agencies, however, after reviewing existing institutional arrangements in their area, recommended that urban storm water quality management should be closely coordinated or combined with control of water quantity.

The City of Bellevue, located in the metropolitan area of Seattle, Washington, between Lakes Washington and Sammamish, (Figure 1) has already moved in that direction. The City embarked on a program of urban storm water quantity and quality management in 1970, well before the passage of P.L. 92-500, by establishing a Storm and Surface Water Utility within its Department of Public Works to administer the design and implementation of an effective storm drainage/stream system in the City. The Utility has a variety of functions related to the operation of the city-wide drainage system, including planning, design, construction, maintenance and operation of the physical system, acquisition and preservation of wetlands, design review of all new developments in the City (with requirements for on-site detention of storm water), field inspection of development and construction practices, water quality and flow quantity monitoring, and land use and flood plain development policy. Fortuitously, Bellevue had three characteristics which made the City especially well suited for implementation of an effective, centralized stormwater management system:

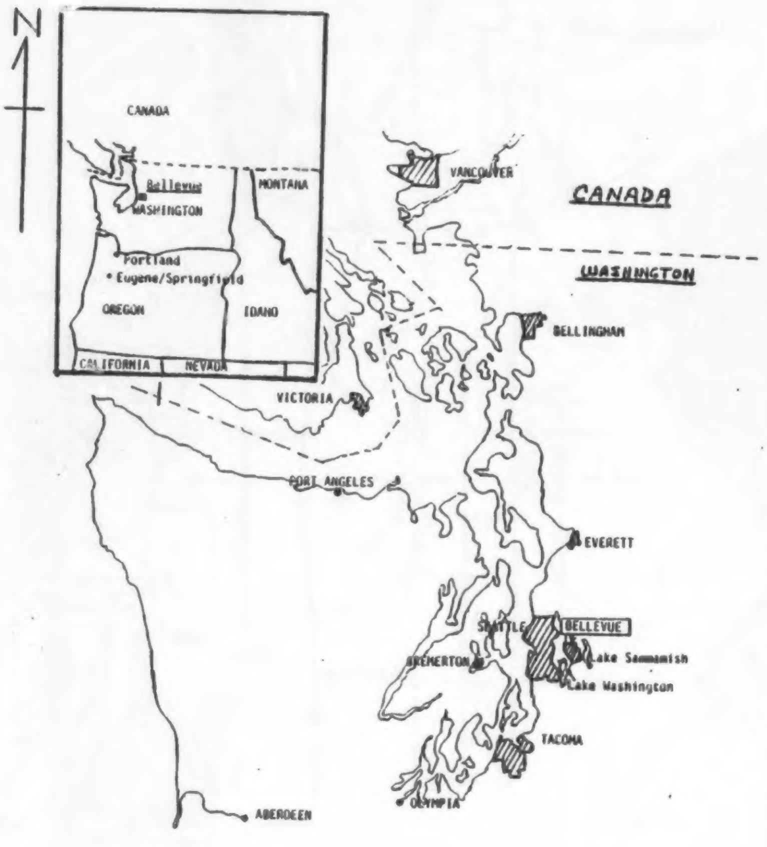
a) an even, continuous supply of rainfall (42 inches/year average);

b) no combined sewer systems in operation within the City limits; and

c) ninety percent of the area's drainage systems located within the Bellevue city limits (the City of Bellevue and Mercer Island are probably the only cities in the Pacific Northwest that will be able to manage their storm water problems from within their respective city limits.

Results of the Bellevue NURP study will be helpful to other agencies contemplating, or already initiating, innovative stormwater management systems, not only in the Pacific Northwest but throughout the nation.

FIGURE 1 - STATE LOCUS OF BELLEVUE NURP



PHYSICAL DESCRIPTION

A. Area

Bellevue, Washington is located in the Puget Sound lowlands on the west side of the Cascade Mountains and immediately east of Lake Washington. It has a land area of 25 square miles. The community is primarily a bedroom community for middle and upper level employees of the aerospace industry located in nearby Seattle. The principal land use is residential with associated commercial development. The mean annual precipitation is about 42 inches, which occurs mainly as rain.

B. Population

Bellevue currently has a population of over 75,000 people. As part of the Bellevue Urban Runoff Project, a demographic survey was conducted in the Lake Hills and Surrey Downs catchments, the two primary catchments monitored during the Project. These results indicate that the population in Lake Hills is approximately 44% higher than that in Surrey Downs. These differences are due in large amounts to the higher housing density in Lake Hills (3.51 houses/acre) as compared to Surrey Downs (2.99 houses/acre).

C. Drainage

The land surface in Bellevue is mostly hilly with very few flat areas. Slopes are generally moderate with the exception of some steep slopes on the east side of the city. Altitudes range from 40 feet on the western boundary to over 400 feet at points on the eastern boundary. Drainage is carried by a system of separate storm sewers, open channels and streams largely to the west into Lake Washington through Mercer Slough although Phantom Lake and one other stream flow east into Lake Sammamish (Figure 2). The surficial geology is typically relatively shallow, sandy soil overlying glacial-till hardpan.

D. Sewerage System

The existing sewerage system serving the City of Bellevue is totally separated. The structural storm drainage system - streets, curbs and gutters, storm inlets, swales, catchbasins and culverts-are in good condition.

The City is served by the Renton wastewater treatment plant which has a current capacity of 36 MGD, provides a secondary level of treatment and discharges into the Duwamish River. Construction to expand the plant's capacity to 72 MGD is nearing completion. A second expansion will then be initiated to carry the plant to its ultimate capacity, 105 MGD.

FIGURE 2 - BELLEVUE STREAM SYSTEMS

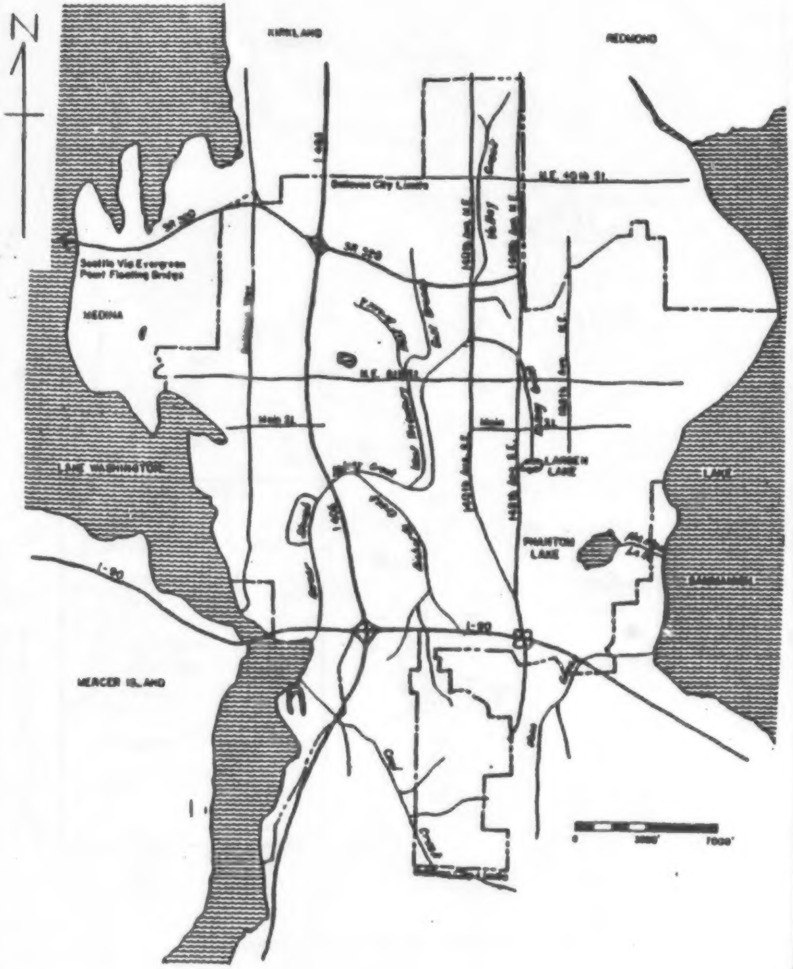
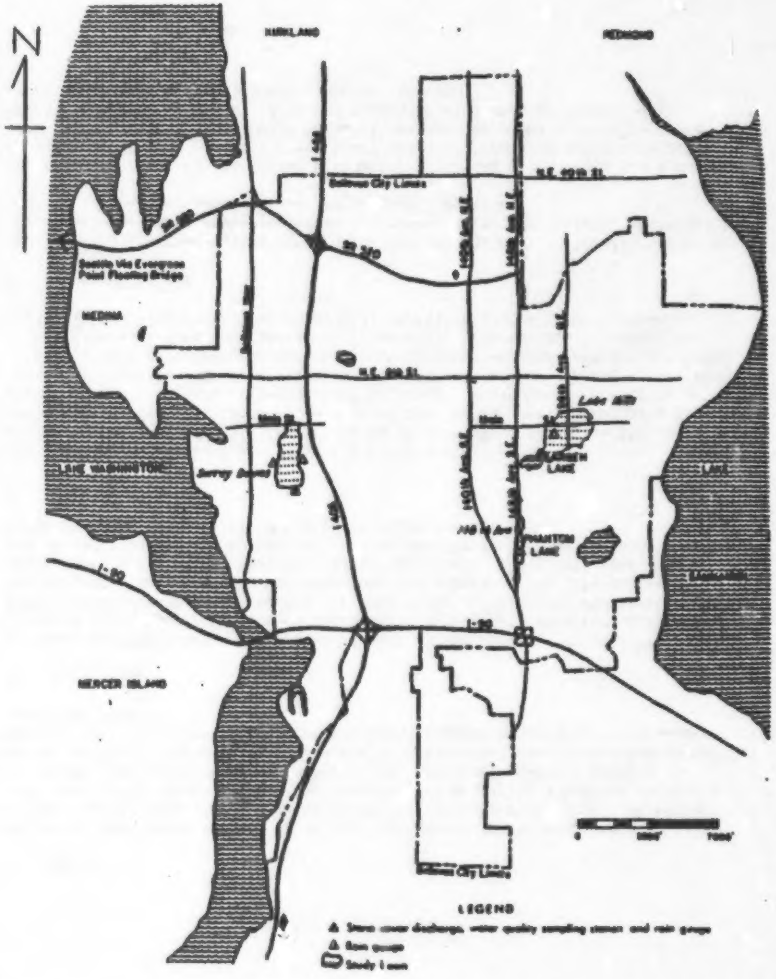


FIGURE 3 - BELLEVUE SAMPLING SITES



PROJECT AREA

I. Catchment Name - Lake Hills: 208 Bell 0586/12119725 - (Both the City of Bellevue (COB) and USGS are monitoring runoff at this site: COB collects flow proportional composites and enters data under station code "208 Bell 0586"; USGS collects selected discrete samples and enters data under "12119725".

A. Area - 101.7 acres.

B. Population - 1185 persons.

C. Drainage - This catchment area has a representatie slope of 317 feet/mile, 100% served with curbs and gutters. The storm sewers approximate a 211 feet/mile slope and extend 3400 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 9.683 lane miles of asphalt, 94% of which is in good condition and 6% of which is in fair condition.

E. Land Use

92 acres (90%) is 2.5 to 8 dwelling units per acre urban residential, of which 33.8 acres (37%) is impervious.

9.7 acres (10%) is Urban Institutional,
of which 3.6 acres(37%) is impervious.

II. Catchment Name - Surrey Downs: 208 Bell 0588/12120005 - (Both COB and USGS are monitoring runoff at this site: COB collects flow proportional composites and enters the data under station code "208 Bell 0588"; USGS collects selected discrete samples and enters data under station code "12120005".)

A. Area - 95.1 acres.

B. Population - 822 persons.

C. Drainage - This catchment area has a representative slope of 475 feet/mile, 84% served with curbs and gutters. The storm sewers approximate a 106 feet/mile slope and extend 3600 feet.

D. Sewerage - Drainage area of the catchment is 100% separate storm sewers.

Streets consist of 6.18 lane miles of asphalt, 65% of which is in good condition, 33% of which is in fair condition, and 2% of which is in poor condition.

E. Land Use

95.1 acres (100%) is 2.5 to 8 dwelling units per acre residential, of which 27.7 acres (29%) is impervious.

III. Catchment Name - 148th Avenue SE: 12119730 (only USGS monitors runoff at this site: selected discrete samples with data entered under station code "12119730".)

IV. Catchment Name - Lake Hills: 208 Bell 0580 - (Particulate data from selected catchbasins within Lake Hills catchment.)

V. Catchment Name - Surrey Downs: 208 Bell 0581 - (Particulate data from selected catchbasins within Surrey Downs catchment.)

VI. Catchment Name - Lake Hills: 208 Bell 0582 - (Street surface particulate loadings from street sweeping within Lake Hills catchment.)

VII. Catchment Name - Surrey Downs - Main Basin: 208 Bell 0583 (Street surface particulate data from the major sub-basin of Surrey Downs catchment.)

Streets consist of 4.787 lane miles of asphalt, 77% of which is in good condition and 23% of which is in fair condition.

VIII. Catchment Name - Surrey Downs - 108th Avenue SE: 208 Bell 0584 (Street surface particulate data from minor sub-basin of Surrey Downs catchment.)

This street, an arterial, is in poor-to-fair condition, has a bumpy surface, has a rolled asphalt curb only on downhill side and is bordered for most its length by vacant land (grass, woods, brush).

IX. Catchment Name - Surrey Downs - Westwood Homes Road: 208 Bell 0585 (Street surface particulate data from minor sub-basin of Surrey Downs catchment.)

This street is a private lane in good-to-excellent condition with a rolled asphalt curb on the downhill side only.

X. Catchment Name - 148th Avenue SE: 208 Bell 0589 (Street surface particulate data from the major portion of a drainage basin sampled only by USGS (12119730)).

This street is a divided arterial in fair-to-good condition.

PROBLEM

A. Local Definition (Government)

As noted in the Introduction, the City of Bellevue, through its Storm and Surface Water Utility. has established an innovative organizational approach to stormwater control. From its inception, the Utility has been under constant pressure from citizens' groups and the general public (details below) to focus its efforts heavily upon improving water quality as well as upon resolving water quality and problems. All waters in and surrounding Bellevue are classified "AA" to support use as fisheries (including salmon) and for contact recreation - swimming, boating and canoeing. But while there has been widespread concern that these standards are being violated or at least are threatened by the rapid development that has characterized Bellevue's recent past, the problem has not been documented with hard data. In part, the Bellevue NURP study is directed at identifying the pollutant loadings from urban runoff.

Additionally, while best management practices (BMPs) were tentatively identified in many Areawide 208 plans and preliminary studies of selected BMPs were conducted, the effectiveness and costs associated with the practices for the most part were only estimated. An urgent need exists to apply and test, under actual field conditions, many of the BMPs identified through the 208 Program. To accurately assess the practices and their cost-effectiveness and to provide "real-world" assessment of the requirements for effective implementation, such analysis should be conducted by an operating local agency in the course of its normal work program.

Bellevue's need for up-to-date, reliable data on pollutant loadings from urban runoff and on the effectiveness and workability of control measures has recently become more urgent as a result of its selection as a test site for a new State stormwater discharge permit program. Under a court order arising from a suit brought against the Washington State Department of Ecology (DOE), the DOE has developed a State general permit program similar to the NPDES General Permit Program which grew out of similar litigation at the national level. Bellevue will be issued the first such permit for a set term and then monitored for permit compliance. Development of a realistic and effective permit will require realistic, reliable data on both existing pollutant levels in runoff discharges and the performance which can reasonably be expected from control measures.

B. Local Perception (Public)

In part due to the presence of a large number of citizens of Scandanavian descent, the City of Bellevue has always treasured its water resources, particularly for fishing. Established at the same time as the Utility itself, the Storm and Surface Water Advisory Commission (SSWAC) functions in an advisory role to the City Council, reviewing the Utility's functions and providing recommendations on policies and ordinances. It is composed of citizens-at-large, many with professional interests and expertise in the water quality area as well (e.g., engineers, professors), and representatives of business and community organizations within the City.

More recently the Bellevue Creeks Committee, which meets monthly, has developed from a cluster of concerned citizens into a working committee identifying water quality goals and stimulating programs aimed at water quality and fisheries enhancement and at wildlife habitat preservation to achieve them. In association with Seattle Metro's Salmon Enhancement Program (SEP), sockeye salmon eggs were incubated in Kelsey Creek from January until March of 1980. Problems with siltation reduced the survival of salmon eggs by approximately 50% but incubation will continue at this and two other sites less vulnerable to siltation. Community support for SEP has been overwhelming. Three local high schools (Bellevue Christian, Bellevue High, and Interlake High) have assisted with construction and box installation. Local sports and service organizations (Eastside Steelwheelers, Overlake Fly Fishing, and Bellevue Kiwanis) have assisted with site preparation; box installation and stream clean-ups. Elementary school groups (Somerset, Wilburton, Three Points, Clyde Hill and Cherry Crest) have seen the eggs taken from Cedar River adult salmon or have seen the slide presentation on SEP. Private citizens and interested groups (Seattle Audubon) assisted in a gruelling silt removal project on Valley Creek. Over forty cubic yards of silt and debris were hand-shovelled onto a conveyor belt to a waiting dump truck in order to clear out a dam which will act as a sediment trap upstream of the new egg box. The popularity of SEP is evidenced by the many news articles published about it and by the television coverage it has received in the past year. However, the significance and value of the Salmon Enhancement Project is far greater than just improving the odds for future salmon runs. It has also served as a high visible, readily understandable and attention-gettin vehicle for educating citizens and local officials about the impacts of stormwater runoff upon water quality and for rallying their support for programs to improve and protect stream quality. It has been a key factor in the passage of ordinances to control discharge of pollutants to the drainage system and in the establishment of related stream management programs.

Public awareness is also generated through programs like Bellevue's Oil Recycling Program. In the summer of 1980 over one-half of the City's service stations agreed to receive used crankcase oil from the public and to publicly identify their stations by posting a sign. Another poster was distributed by local Boy and Girl Scout troops to merchants that sell oil. One of the most significant accomplishments of the Creeks Committee, however, was the recent passage of the storm drainage advisory ballot for the sale of $10 million of revenue bonds for urban runoff capital improvements.

PROJECT DESCRIPTION

A. Major Objectives

This study provides a well documented assessment of the application, cost and effectiveness of BMP's for urban storm water quality control within an operating local agency of government. In cooperation with the United States Geological Survey, the City has applied a variety of structural, non-structural and operational management practices in several small watersheds and monitored the cost of such practices and their effect upon quality conditions. Specifically, the study seeks:

- To apply uniformly, in selected drainage basins, a variety of management practices which are availabe to and achievable by local units of government;
- To improve standard practices and operations by varying the frequency and manner of application, developing management programming methods and altering monitoring and inspection practices for greater responsiveness to water quality needs;
- To test, analyze and document the impact of local management practices on storm water quality, isolating causal factors and their impacts on water quality and evaluating and developing functional relationships between the quantity and quality of runoff and the hydrologic and cultural characteristics of the basins involved;
- To develop, test and document methods of source control of common urban storm water pollutants;
- To document temporal changes in storm runoff and constituent concentrations within several drainage basins of differing land use;
- To develop and document means of incorporating best management practices into the institutional and operational framework of local government agencies;
- To expand the toxic metals, sediment, herbicides and pesticides, and other data base for various land use categories, contributing to the data base of storm water quality modeling efforts nationally;
- To develop methods for estimating storm and annual loads of water-quality constituents from unsampled watersheds in each urban-study area; and
- To evaluate methods of transfering the data to ungaged watersheds in other regions.

B. Methodologies

As its part of the cooperative study, USGS is carrying out continuous monitoring of precipitation on three urban catchments, and the resultant discharge from these catchments; the collection and chemical analysis of rainfall and dry deposition samples, both of which are composited over periods of time varying from fractions of a day to a month; and the collection of discrete samples of runoff to define pollutant hydrographs for each of the catchments during approximately 12 storms per year.

For its part, the City of Bellevue is gathering composite samples of stormwater runoff from two urban catchments (Surrey Downs and Lake Hills) as well as catchbasins and street particulate samples from the same two catchments. Street sweeping evaluation is accomplished by using one of the basins as a control, with no sweeping, while the other is swept intensively. A period of no sweeping in either basin follows. Then the swept basin and control basin are reversed. The major objective of this part of the study is to determine the effectiveness of street cleaning equipment for various levels of effort under the actual conditions encountered. The most important measure of street cleaning effectiveness is "pounds per curb-mile removed" for a specific program condition. This removal value, in conjunction with the unit curb-mile costs, allows the cost for removing a pound of pollutant for a specific street cleaning program to be calculated.

An important element of the Bellevue urban runoff project is the study of sewerage system particulate deposition and scour. The objective of this portion of the program is to describe the quantities and characteristics of sewerage system particulates in the study area. The sewer system particulate studies involve both observation and sampling of catchbasin particulates and particulates accumulated in the pipes throughout the Lake Hills and Surrey Downs study areas. Data obtained from these studies will be compared to monitored street surface loadings and total runoff yields measured at the outfalls of the two study areas. Analysis procedures will attempt to obtain a continuous mass balance relationship between total runoff yields and all the sources of urban runoff pollution. These mass relationships will define the importance of sewerage solids to the total runoff yield. It will also provide an insight to the residence time of particulates within the sewage system and how these times are affected by runoff from adjacent storms.

The municipality of Metropolitan Seattle (Metro) is participating in the Bellevue Urban Runoff Project under a grant entitled the "Toxicant Inventory." This grant allows Metro to have samples that are collected in the Bellevue Project analyzed for the 129 EPA toxic or "priority" pollutants. All except asbestos are being looked for at the part per billion range in these samples. Sampling through the summer and fall of 1980 resulted in the collection of seventeen samples. Decisions on the remaining samples were made based on careful review of the results of those samples. The stormwater runoff and street dust samples for priority pollutant analyses are all split samples from the Bellevue Project collected by Bellevue staff and handled in such a way as to minimize sample contamination.

C. Monitoring

Two of the three study catchments, Surrey Downs and Lake Hills, are single-family residential areas of similar size. These two basins are used to investigate the effectiveness of street sweeping for reducing the amount of pollutants in storm runoff. The third catchment, 148th Avenue, consists mainly of a divided 4-lane arterial street. The data from this site are used to investigate the effects of detention basins on the quality of runoff.

The area comprising the Surrey Downs catchment consists of single family homes and the Bellevue Senior High School. Slopes in the basin are generally moderate, with the exception of the steep slopes on the west side. Surrey Downs is relatively isolated from neighboring communities by the general lack of easy vehicular access and convenient "short cuts" through this residential neighborhood.

The Lake Hills catchment contains single family residences and the St. Louise Parish Church and School. Although there are relatively isolated residential areas within the catchment, two through-streets, which carry more traffic than a typical residential street, cross the area.

The 148th Avenue catchment contains 4,960 feet of 148th Avenue, a four-lane, divided arterial street, and some adjacent land with sidewalks, apartments, parking lots, office buildings, and grassy swales that can be used as detention basins. A little over one-fourth of the catchment area is taken up by the 148th Avenue street surface.

USGS sample collection and management procedures are essentially the same at all three sites. A digital paper punch recorder records: (1) clock time, (2) a number code which indicates if a sample was taken by the automatic sampler, (3) accumulated precipitation in up to three rain gages, and (4) up to two stages for computing discharge. Data are recorded at 5-minute intervals whenever the gage exceeds a present threshold or whenever there is measurable precipitation. In addition, data are recorded at 1:00 a.m. every day regardless of stage or precipitation. Precipitation is measured with tipping-bucket rain gages. Three gages are operated for the Surrey Downs catchment and two each are operated for the Lake Hills and 148th Avenue catchments. Rainfall and dry deposition quality samples are collected at one location in each catchment. Discrete runoff samples are taken during storms for defining the temporal variation of water quality during storm hydrographs. Samples are taken at a preset time interval (5 to 50 minutes) once the stage exceeds a preset threshold.

The procedures and techniques used by Bellevue for collecting composite flow and proportional stormwater runoff samples are as follows. The sampler is triggered at pre-determined increments of flow by the flowmeter (300 and 500 cubic feet the former to obtain more subsamples when small events were expected). The flowmeters use an ultrasonic transducer to sense relative stage. Stage is converted to discharge by a programmed microprocessor in the flowmeter and presented on a circular flow chart as a percentage of maximum rated flow. The microprocessor is programmed from a stage/discharge rating developed by the USGS. Storm samples are removed from the samplers as soon as possible after storms, typically within two or three hours. Samples are kept on ice until pH, conductivity and turbidity are measured in-house. Subsamples are preserved and sent to a contract lab in Seattle for the remaining chemical analysis.

To obtain street surface particulate samples the City of Bellevue used the following procudures. Because the street surfaces were more likely to be dry during daylight hours (necessary for good sample collection), collection did not begin before sunrise nor continue after sunset, unless additional personnel were available for traffic control. Subsamples were collected in a narrow strip about six inches wide (the width of the gulper) from one side of the street to the other (curb-to-curb). In heavily traveled streets where traffice was a probelm, some subsamples consisted of two separate half-street strips (curb-to-crown).

To carry out the catch basin sampling tasks, all catch basins in each study area were surveyed for location, length, size and slope of pipes, and depth of catchment. Another survey was done to record the dimensions of each catch basin. Sediment volume could then be calculated from a measurement of sediment depth.

Some experimental design work was done in 1979 and early 1980 to determine the concentrations of some pollutant constituents. Grab samples of supernatant and sediment were taken from selected catch basins in each study area and submitted to a contract lab for chemical analysis. During 1980, two complete catch basin inventories were made; recording sediment depth, and thus mass loading in the system. Monthly inventories are scheduled for 1981. Since December, 1980, spot checks of fifteen to twenty-five selected catch basins in each study area have been made after each significant storm event. This information, along with storm and street loading data should allow characterization of flushing and deposition within the sewerage system.

For the toxicant inventory portion of the study, stormwater runoff samples are collected as flow proportioned composites using Manning S3000T automated samplers -- all teflon and glass contact surfaces -- activated by ultrasonic flowmeters, except for the volatile samples which are collected as grabs early in the storm events. Samplers and containers are cleaned between events according to USEPA protocols using "Micro" brand soap and nitric acid; the hyrochloric acid and methylene chloride rinses are not used. Deionized distilled water blanks are taken through each sampler before use and have proven to be completely clean of organic and metal contaminants. Street surface dust samples are collected as described above using a stainless steel vacuum and PVC flexible hose. No special cleaning protocol has been applied to the vacuum. Some sample contamination could occur from the PVC hose, but no functional alternatives has been found for collecting the dust samples. Interstitial water samples from the stream-bed in Kelsey Creek are collected through aluminum standpipes set in the stream gravel, using a Manning S3000T sampler to draw the water up from the perforated base of the standpipe. This sampling is in conjunction with the "Ecological Impacts of Stormwater Runoff in Urban Streams" project of the University of Washington.

D. Equipment

The equipment used by the City of Bellevue at the Lake Hills and Surrey Downs sites for flow-weighted composite stormwater monitoring consists of a Manning composite sampler (S-3000), a Manning flowmeter with an ultrasonic stage sensor (UF-1100) and a 12 volt power converter. The samplers were factory modified for priority pollutant sampling. All surfaces contacting the sampler are either glass or teflon.

For the USGS sampling effort at Lake Hills, Surrey Downs and 148th St., at walk-in instrument shelter was constructed near the mouth of each catchment for housing a data recording system and sample control and collection system. A digital paper punch recorder records: (1) clock time, (2) a number code which indicates if a sample was taken by the automatic sampler, (3) accumulated precipitation in up to the three rain gages, and (4) up to two stages for computing discharge.

For the City's street sampling task various vacuum, hose and gulper attachment combinations were tested. Relative air flows and suction pressures in the hose were monitored for different test set-ups. Both one-and two-vacuum configurations and 1.5 inch hoses in lengths varying from 10 to 35 feet were tested, along with a Vacu-Max unit. The standard "reference" system was two vacuums and a 35-foot hose. The best suction and higher air velocities were observed with two vacuums and short hose lengths (10 feet), but the short hose length would require that the vacuums be dismounted from the truck at each subsampling location. The longer hose, with the two vacuums, was judged adequate, and resulted in great cost and time savings.

A pick-up truck was used to carry the equipment components, consisting of a generator, tools, fire extinguisher, vacuum hose and wand, and two wet-dry vacuum units during sample collection. The truck had warning lights, including a roof-top flasher unit.

Two industrial vacuum cleaners (2-hp) with one secondary filter and a primary dacron filter bag were used. The vacuum units were heavy duty and made of stainless steel to reduce contamination of the samples. the two 2-hp vacuums were used together by using a wye connector at the end of the hose. This combination extended the useful length of the 1.5 inch hose to 35 feet and increased the suction. A wand and a gulper attachment were also used.

E. Controls

Alternate streetsweeping in the Lake Hills and Surrey Downs basins, using the unswept basin as a control, was described earlier. The other control being evaluated is a unique, small, short-term detention basin at 148th St. The storm sewer system consists of a main trunk line parallel to the street, which is fed by short laterals that connect to catchbasins in 148th Avenue and in adjacent lands. The sewer has a complex system of gates and valves in five junction boxes that permit the storm water to be backed up into five grassy swales which serve as detention basins.

NATIONWIDE URBAN RUNOFF PROGRAM
EUGENE/SPRINGFIELD, OREGON
REGION X, EPA

INTRODUCTION

The Eugene/Springfield Metropolitan Area has a population of just over 200,000 people and has been experiencing moderately rapid growth. Much of the storm runoff for the area is collected in open channels that serve multiple-use function including open space, flood control, drainage, recreation and irrigation. Significant portions of the runoff so collected discharge secondarily to the Willamette River inside the metro area. Eugene and Springfiled are at points in their development where recent growth is outstripping the existing drainage capacity. At the same time, more and more growth is occurring in hill areas where problems are erosion and peak flow are being exacerbated. Complicating these developments is the general desire to concentrate growth in the central urban areas and the increasingly strongly felt need to preserve water-oriented open spaces and parks. Hence, a timely reconsideration of the physical demands of runoff control coincides with the increasing need to control runoff quality, and if solutions to both of these problems are not developed in the next several years, serious service cost escalations and compromises in beneficial uses are to be expected.

Urban stormwater runoff pollution from the Eugene/Springfield Metropolitan Area has been identified as a significant source of contamination to local streams and water bodies on an annual average as well as during peak storm events. Of particular concern are spills and accidental discharges of oil, grease and industrial chemicals during high runoff periods. This contamination causes a variety of problems ranging from specific and localized health hazards in water recreation areas to a more general degradation of streams and chronic interference with downstream beneficial uses. In-stream water quality standard violations have been observed as a regular result of this contamination. Under an initial 208 Grant problems were identified and potential control options developed. The NURP grant is being used to complete this process by identifying and developing specific and adoptable management programs.

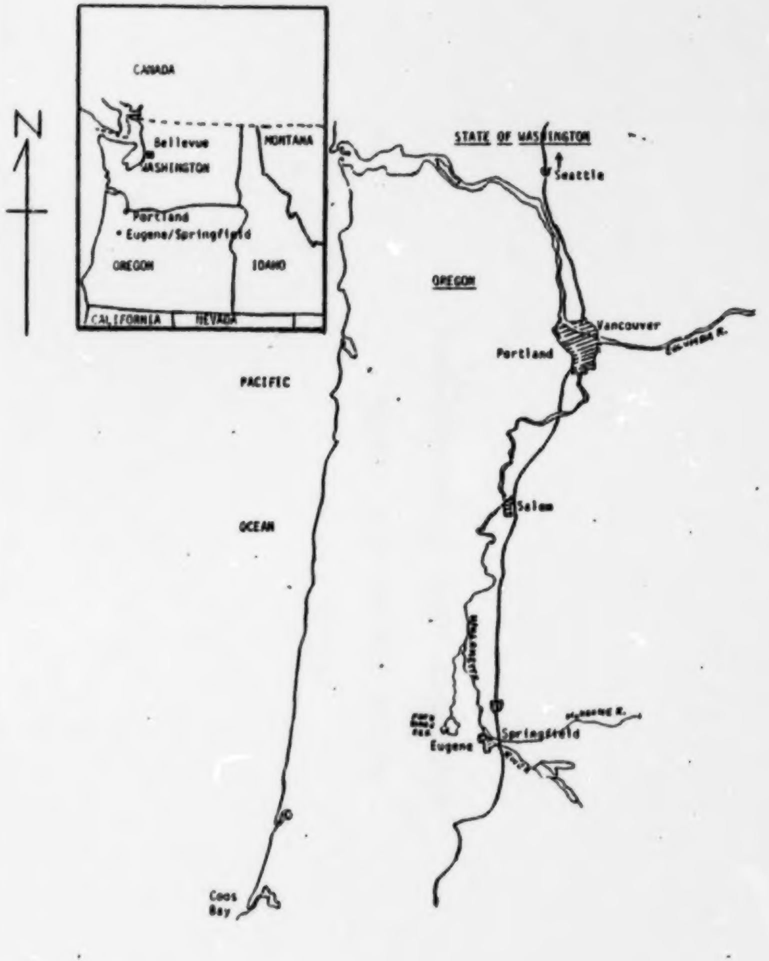


FIGURE 1 - STATE LOCUS OF EUGENE/SPRINGFIELD NURP PROJECT

PHYSICAL DESCRIPTION

A. Area

The Eugene/Springfield Metropolitan Area is located in western Oregon approximately 55 miles inland from the Pacific coastline and 100 miles south of Portland. The total land area of the two jurisdictions totals just over 29,000 acres.

B. Population

Eugene/Springfield is a growing metropolitan center whose current population of 190,000 is expected to reach 300,000 by the year 2000. The City of Eugene has 102,000 people, Springfield has 43,000 and 45,000 people reside in the semi-urban unincorporated areas of River Road and Santa Clara.

C. Drainage

Much of the area is of flat topography with occasional prominences above the 130-meter valley elevation. The southern portion of both cities are bordered by hills rising 100-250 meters above the surrounding flatlands. Natural drainages in this area are of basically two types - intermittent and semi-permanent small-hill drainages, and long flood channels that drain the alluvial flats. Some streams, such as Amazon Creek, are combinations of hill drainages and extended flood channels. An exception is Spring Creek, which is fed from groundwater springs. Nearly all of the channels have been at least partially altered by man. In particular, Amazon Creek has been deepened, channelized in most lower reaches, concrete lined in the city center and diverted from its flood swale west of Eugene towards Fern Ridge Reservoir. The "Q" Channel is a channelized flood swale to which a McKenzie River connection was added for irrigation and to which side channels have been attached for runoff drainage. Near its lower end a park pond has been created and Willamette River waters diverted via a canoe way to increase the flow.

The drainages are highly variable in their flow volumes with summer flows running 0-1 cfs. and winter maxima reaching 100 to 1000 times that volume. The Amazon Creek has been known to exceed 1000 cfs. west of Eugene. In the south hills and in western sections of Eugene where heavy, clay soils predominate, runoff response to rainfall is rapid, while in the central and northern areas of Eugene and Springfield, the presence of pervious soils means that stream flow will often not increase until soils are saturated and the shallow water table has risen to the stream bottom level.

D. Sewerage System

A piped stormwater drainage system directs runoff into open channels which carry the waters north and west to receiving waters such as Fern Ridge Reservoir or the Willamette River. The stormwater drainage systems in both cities are generally separated from the sanitary sewer systems but storm overflow connections do exist. Eugene and Springfield are currently each served by wastewater treatment plants providing a secondary level of treatment. A 50-MGD advanced secondary wastewater treatment facility to serve the whole Metropolitan Area will be completed in 1983.

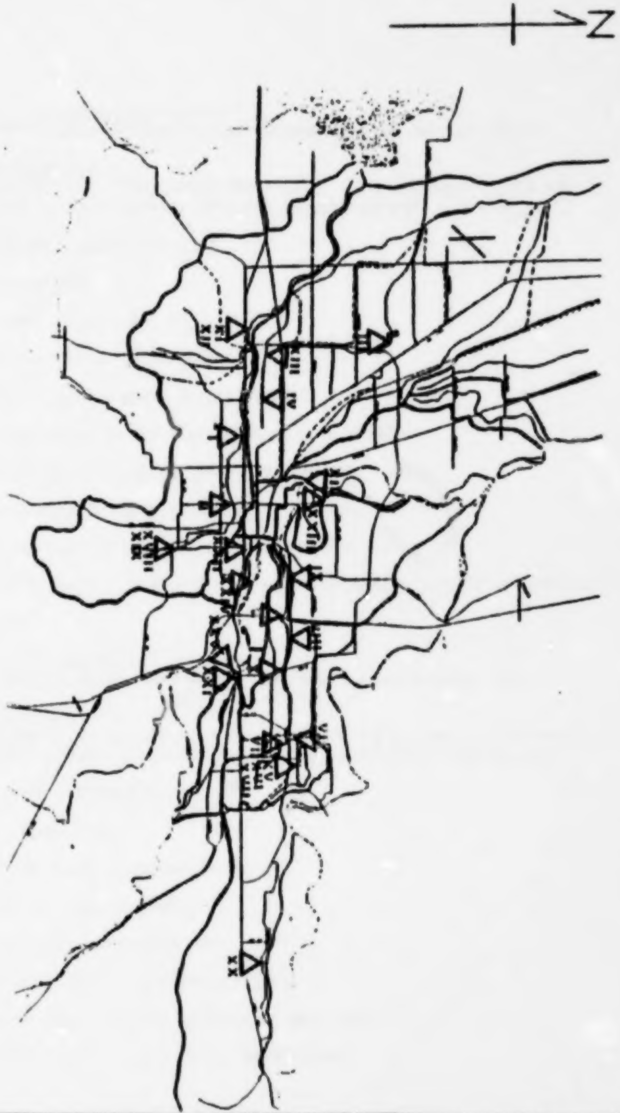


FIGURE 2 - MONITORING BASINS AND SAMPLING SITES FOR EUGENE/SPRINGFIELD NURP PROJECT

MONITORING STATIONS, CATCHMENTS, AND RECEIVING WATERS

I. Catchment Name - Amazon at Oakpatch (limited data)

A. Area - 6951 acres.

B. Population - 45,210 persons.

C. Drainage - This catchment area has a representative slopeof 320 feet/mile. The storm sewers approximate a 19.6% feet/mile slope and extend 30,140 feet.

D. Sewerage - Drainage area of the catchment is 60% separate storm sewers and 40% with no sewers.

E. Land Use

2000 acres (29%) is 0.5 to 2 dwelling units per acre Urban Residential.

1500 acres (22%) is 2.5 to 8 dwelling units per acre Urban Residential.

300 acres (4%) is > 8 dwelling units per acre Urban Residential.

200 acres (3%) is Linear Strip Development.

41 acres (<1%) is Urban Industrial (moderate).

400 acres (16%) is Urban Parkland or Open Space.

460 acres (7%) is Urban Institutional.

550 acres (8%) is Agriculture.

1500 acres (22%) is Forest.

II. Catchment Name - Amazon at Washington

A. Area - 4745 acres.

B. Population - 28,830 persons.

C. Drainage - This catchment area has a representative slope of 355 feet/mile. The storm sewers approximate a 26.1% feet/mile slope and extend 19,730 feet.

D. Sewerage - Drainage area of the catchment is 55% separate storm sewers and 45% without sewers.

E. Land Use

1400 acres (30%) is 0.5 to 2 dwelling units per acre Urban Residential.

810 acres (17%) is 2.5 to 8 dwelling units per acre Urban Residential.

280 acres (6%) is > 8 dwelling units per acre Urban Residential.

125 acres (3%) is Linear Strip Development.

270 acres (6%) is Urban Parkland or Open Space.

260 acres (5%) is Urban Institutional.

400 acres (8%) is Agriculture.

1200 acres (25%) is Forest.

III. Catchment Name - A-2 at Golden Garden

A. Area - 1655 acres.

B. Population - 7,570 persons.

C. Drainage - This catchment area has a representative slope of 8.8 feet/mile. The storm sewers approximate a 7.6 feet/mile slope and extend 14,400 feet.

D. Sewerage - Drainage area of the catchment is 40% separate storm sewers and 60% without sewers.

E. Land Use

730 acres (44%) is 2.5 to 8 dwelling units per acre urban Residential.

115 acres (7%) is Linear Strip Development.

30 acres (2%) is Urban Industrial (moderate).

250 acres (15%) is Urban Industrial (heavy).

280 acres (17%) is Urban Parkland or Open Space.

100 acres (6%) is Urban Institutional.

150 acres (9%) is Agriculture.

IV. Catchment Name - A-3 at Wallis

A. Area - 565 acres.

B. Population - 190 persons.

C. Drainage - This catchment area has a representative slope of 9.2 feet/mile. The storm sewers approximate a 2.4 feet/mile slope and extend 3700 feet.

D. Sewerage - Drainage area of the catchment is 30% separate storm sewers and 70% without sewers.

E. Land Use

4 acres (1%) is 2.5 to 8 dwelling units per acre Urban Residential.

2 acres (<1%) is > 8 dwelling units per acre Urban Residential.

74 acres (13%) is Linear Strip Development.

127 acres (22%) is Urban Industrial (light).

85 acres (15%) is Urban Industrial (moderate).

190 acres (34%) is Urban Industrial (heavy).

85 acres (15%) is Urban Parkland or Open Space.

V. Catchment Name - Q Street at Garden Way

A. Area - 4428 acres.

B. Population - 27,300 persons.

C. Drainage - This catchment area has a representative slope of 14 feet/mile. The storm sewers approximate a 9.8 feet/mile slope and extend 27,000 feet.

D. Sewerage - Drainage area of the catchment is 50% separate storm sewers and 50% without sewers.

E. Land Use

670 acres (15%) is 0.5 to 2 dwelling units per acre Urban Residential.

1305 acres (29%) is 2.5 to 8 dwelling units per acre Urban Residential.

219 acres (5%) is > 8 dwelling units per acre Urban Residential.

180 aces (4%) is Linear Strip Development.

45 acres (1%) is Shopping Center.

110 acres (2%) is Urban Industrial (moderate).

240 acres (6%) is Urban Industrial (heavy).

810 acres (18%) is Urban Parkland or Open Space.

199 acres (5%) is Urban Institutional.

650 acres (15%) is Agriculture.

VI. Catchment Name - Q Street North Branch

A. Area - 576 acres.

B. Population - 550 persons.

C. Drainage - This catchment area has a representative slope of 12 feet/mile. The storm sewers approximate a 10.5 feet/mile slope and extend 8500 feet.

D. Sewerage - Drainage area of the catchment is 100% without sewers.

E. Land Use

40 acres (7%) is 0.5 to 2 dwelling units per acre Urban Residential.

5 acres (1%) is > 8 dwelling units per acre Urban Residential.

70 acres (12%) is Urban Industrial (heavy).

135 acres (23%) is Urban Parkland or Open Space.

26 acres (5%) is Urban Institutional.

300 acres (52%) is Agriculture.

VII. Catchment Name - Q Street South Branch

A. Area - 1170 acres.

B. Population - 6670 persons.

C. Drainage - This catchment area has a representative slope of 14 feet/mile. The storm sewers approximate a 10.5 feet/mile slope and extend 10,500 feet.

D. Sewerage - Drainage area of the catchment is 80% separate storm sewers and 20% without sewers.

E. Land Use

450 acres (38%) is 2.5 to 8 dwelling units per acre Urban Residential.

95 acres (8%) is > 8 dwelling units per acre Urban Residential.

95 acres (8%) is Linear Strip Development.

25 acres (2%) is Shopping Center.

100 acres (9%) is Urban Industrial (heavy).

80 acres (7%) is Urban Industrial (moderate).

300 acres (26%) is Urban Parkland or Open Space.

25 acres (2%) is Urban Institutional.

VIII. Catchment Name - Q Street at Quinalt (monitored under previous 208 Study)

A. Area - 2985 acres.

B. Population - Approximately 23,000 persons.

C. Drainage - This catchment area has a representative slope of a 15 feet/mile. The storm sewers approximate a 10 feet/mile slope and extend 23,800 feet.

D. Sewerage - Drainage area of the catchment is 90% separate storm sewers and 10% without sewers.

E. Land Use

230 acres (8%) is 0.5 to 2 dwelling units per acre Urban Residential.

1105 acres (37%) is 2.5 to 8 dwelling units per acre Urban Residential.

139 acres (5%) is > 8 dwelling units per acre Urban Residential.

145 acres (5%) is Linear Strip Development.

45 acres (2%) is Shopping Center.

100 acres (3%) is Urban Industrial (moderate).

190 acres (6%) is Urban Industrial (heavy).

610 acres (20%) is Urban Parkland or Open Space.

121 acres (4%) is Urban Institutional.

300 acres (10%) Agriculture.

IX. Catchment Name - Q Street at Centennial

A. Area - 4736 acres.

B. Population - 28,030 persons.

C. Drainage - This catchment area has a representative slope of 14 feet/mile. The storm sewers approximate a 9.8 feet/mile slope and extend 34,500 feet.

D. Sewerage - Drainage area of the catchment is 50% separate storm sewers and 50% without sewers.

E. Land Use

670 acres (14%) is 0.5 to 2 dwelling units per acre Urban Residential.

1305 acres (28%) is 2.5 to 8 dwelling units per acre Urban Residential.

219 acres (5%) is > 8 dwelling units per acre Urban Residential.

215 acres (5%) is Linear Strip Development.

45 acres (1%) is Shopping Center.

110 acres (2%) is Urban Industrial (moderate).

240 acres (5%) is Urban Industrial (heavy).

885 acres (19%) is Urban Parkland or Open Space.

250 acres (5%) is Urban Institutional.

787 acres (17%) is Agriculture.

X. Catchment Name - Q Street at Second

A. Area - 2793 acres.

B. Population - 14,840 persons.

C. Drainage - This catchment area has a representative slope of 13 feet/mile. The storm sewers approximate an 8.6 feet/mile slope and extend 18,500 feet.

D. Sewerage - Drainage area of the catchment is 95% separate storm sewers and 5% is without sewers.

E. Land Use

190 acres (7%) is 0.5 to 2 dwelling units per acre Urban Residential.

1020 acres (37%) is 2.5 to 8 dwelling units per acre Urban Residential.

137 acres (5%) is > 8 dwelling units per acre Urban Residential.

140 acres (5%) is Linear Strip Development.

45 acres (2%) is Shopping Center.

100 acres (4%) is Urban Industrial (moderate).

190 acres (7%) is Urban Industrial (heavy).

550 acres (20%) is Urban Parkland or Open Space.

121 acres (4%) is Urban Institutional.

300 acres (11%) is Agriculture.

XI-XII. Catchment Name - Amazon Vegetation 1,2,3 - Downstream, Mid-Site and Upstream

A. Area - 11,321 acres.

B. Population - 52,310 persons.

C. Drainage - This catchment area has a representative slope of 270 feet/mile. The storm sewers approximate a 15.6 feet/mile slope and extend 43,077 feet.

D. Sewerage- Drainage area of the catchment is 60% separate storm sewer and 40% without sewers.

E. Land Use

2800 acres (25%) is 0.5 to 2 dwelling units per acre Urban Residential.

1860 acres (16%) is 2.5 to 8 dwelling units per acre Urban Residential.

420 acres (4%) is > 8 dwelling units per acre Urban Residential.

350 acres (3%) is Linear Strip Development.

81 acres (1%) is Urban Industrial (moderate).

60 acres (1%) is Urban Industrial (heavy).

650 acres (6%) is Urban Parkland or Open Space.

600 acres (5%) is Urban Institutional.

2400 acres (21%) is Agriculture.

2100 acres (19%) is Forest.

XIII. Catchment Name - A-3 at Bertelsen

A. Area - 1056 acres.

B. Population - 200 persons.

C. Drainage - This catchment area has a representative slope of 8.4 feet/mile. The storm sewers approximate a 4.2 feet/mile slope and extend 6,000 feet.

D. Sewerage - Drainage area of the catchment is 25% separate storm sewers and 75% without sewers.

E. Land Use

2 acres (<1%) is 0.5 to 2 dwelling units per acre Urban Residential.

4 acres (<1%) is 2.5 to 8 dwelling units per acre Urban Residential.

2 acres (<1%) is > 8 dwelling units per acre Urban Residential.

93 acres (9%) is Linear Strip Development.

165 acres (16%) is Urban Industrial (light).

116 acres (11%) is Urban Industrial (moderate).

239 acres (23%) is Industrial (heavy).

435 acres (41%) is Urban Parkland or Open Space.

XIV. Catchment Name - Polk Stormsewer

A. Area - 771 acres.

B. Population - 6600 persons.

C. Drainage - This catchment area has a representative slope of 5.3 feet/mile.

E. Land Use

254 acres (33%) is 2.5 to 8 dwelling units per acre Urban Residential.

50 acres (6%) is > 8 dwelling units per acre Urban Residential.

227 acres (29%) is Central Business District.

114 acres (15%) is Linear Strip Development.

32 acres (5%) is Urban Industrial (light).

34 acres (5%) is Urban Industrial (moderate).

50 acres (6%) is Urban Parkland or Open Space.

10 acres (1%) is Urban Institutional.

XV. Catchment Name - Marcola Ditch 2 - Above E. Bale

A. Area - 16 acres.

B. Population - 0 persons.

E. Land Use

16 acres (100%) is Urban Industrial (heavy).

XVI. Catchment Name - Marcola Ditch 3 - Above W. Bale

A. Area - 4 acres.

B. Population - 0 persons.

E. Land Use

4 acres (100%) is Urban Industrial (heavy).

XVII. Catchment Name - Marcola Ditch 1 - Below Oil Trap

A. Area - 20 acres.

B. Population - 0 persons.

E. Land Use

20 acres (100%) is Urban Industrial (heavy).

XVIII. Catchment Name - Amazon above 29th Sed. Trap

A. Area - 3066 acres.

B. Population - 13,640 persons.

C. Drainage - This catchment area has a representative slope of 4.50 feet/mile. The storm sewers approximate a 39 feet/mile slope and extend 10,750 feet.

D. Sewerage - Drainage area of the catchment is 40% separate storm sewers and 60% without sewers.

E. Land Use

1120 acres (37%) is 0.5 to 2 dwelling units per acre Urban Residential.

160 acres (5%) is > 8 dwelling units per acre Urban Residential.

33 acres (1%) is Linear Strip Development.

38 acres (1%) is Urban Parkland or Open Space.

145 acres (5%) is Urban Institutional.

400 acres (13%) is Agriculture.

1170 acres (38%) is Forest.

XIX. Catchment Name - Amazon at 29th - Below Sed. Trap

A. Area - 3066 acres.

B. Population - 13,640 persons.

C. Drainage - This catchment area has a representative slope of 450 feet/mile. The storm sewers approximate a 41 feet/mile slope and extend 10,800 feet.

D. Sewerage - Drainage area of the catchment is 40% separate storm sewers and 60% without sewers.

E. Land Use

1120 acres (37%) is 0.5 to 2 dwelling units per acre Urban Residential.

160 acres (5%) is > 8 dwelling units per acre Urban Residential.

33 acres (1%) is Linear Strip Development.

38 acres (1%) is Urban Parkland or Open Space.

145 acres (5%) is Urban Institutional.

400 acres (13%) is Agriculture.

1170 acres (38%) is Forest.

XX. Catchment Name - 72nd at Thurston (discharge to McKensie River)

A. Area - Approximately 700 acres.

B. Population - 870 persons.

C. Drainage - This catchment area has representative slope of 720 feet/mile. The storm sewers approximate a 30 feet/mile slope and extend 2500 feet.

D. Sewerage - Drainage area of the catchment is 15% separate storm sewers and 85% without sewers.

XXI. Receiving Waters - Springfield Mill Race near Willamette River.

XXII. Receiving Waters - Eugene Mill Race at Mill Street (limited data).

XXIII. Receiving Waters - Willamette River at Valler River Footbridge.

XXIV. Receiving Waters - Williamette River at Autzen Footbridge.

XXV. Receiving Waters - Williamette River at Highway 126 Bridge.

PROBLEM

A. Local Definition (Government)

Past studies in the Eugene/Springfield Metropolitan Area have included an industrial survey, a data-supported STORM II modeling of major basin hydroland pollutograph predictions, development of lists of problem areas and potential abatement techniques, compilations of existing ordinances and charter powers, and considerable public involvement effort. The local jurisdictions have been convinced by these studies that a general problem exists and that certain areas, such as Amazon Creek, Springfield and Eugene Millraces, the A-3 Channel, and the "Q" Street Channel, are of special concern because of their existing and potential uses.

Local data is presently insufficient, however, to support specific program findings such as, for example, that lead in a problem in the Millraces but organics and oil are the major concern in the "Q" Street Channel. Similarly, although national data provides a guide for preliminary controls selection, the data is presently insufficient to determine that, for example, under the conditions which exist in Eugene/Springfield, vaccum sweeping rather than catch basin cleaning will provide the needed 60% reduction in sediment loads at the same cost factor. Until morespecific answers to these questions can be provided, the jurisdictions are unlikely to adopt effective and implementable ordinances or plans or actually to commit their public works efforts to a comprehensive program of controls.

As a result of earlier studies, especially the Lane COG 208 Plan, matrices were prepared to identify the relationships between critical problem areas, potential management options, pollution impacts and the present state of knowledge. These matrices pointed out large gaps in the existing knowledge of certain pollutant problems and physical management options. In addition they showed that the most thoroughly researched options (ordinances) also have the lowest level of benefits for many of the local priority areas. The problem therefore, is one of gathering selected additional data on known local areas of concern, using this data to evaluate the costs and local utility of various stormwater runoff control measures, choosing from among a range of control options, and then developing schema for the implementation of this option. The goal will be to find control methods sufficient to protect beneficial uses in areas of concern (25-75% pollution reduction) and to provide a lesser degree of abatement (10-40% reduction) in other major drainages.

B. Local Perception (Public Awareness)

Local officials, citizen groups and the public at large have shown an increased awareness of, and a desire to support, storm runoff control efforts and have provided strong support, administratively and financially, for past efforts. From the inception of the multi-year L-COG "208" planning effort, a broadly representative Citizens Advisory Committee was closely and actively involved in the identification and assessment of stormwater runoff problems in the Eugene/Springfield area and possible solutions to them. In addition to providing frequent advice and comments to local elected and appointed officials throughout all stages of the L-COG 208 planning project, the Citizens Advisory Committee regularly communicated the findings of the 208 study to the public as a whole and stimulated discussions of the leading issues through newsletters, workshops and public meetings. As the planning process moved closer to the implementation phase, the CAC was replaced by a 208 Areawide Advisory Committee which is more oriented to policy formulation.

Two documents in particular received wide distribution and attention. The "Urban Stream or Open Sewer" newsletter, distributed in 1977, discussed general problems with runoff potential impacts upon the beneficial uses of urban waters and the future of runoff management. A mailout brochure relating "Urban Water Pollution and Hazardous Wastes" was developed and mailed out in utility billing in 1978 to over 55,000 residences. The focus of this information was to the proper disposal of hazardous wastes that might otherwise end up in storm drains. Recycling was emphasized.

As a result of the activities of the Citizen Advisory Committe and other environmentally orientad citizen organizations, there is a high degree of sensitivity to actual and potential stormwater runoff problems among both public officials and the public as a whole. In addition, several accidents and oil spills resulting in fish kills have highlighted the need for spill prevention and toxic chemical control measures. There is widespread support, in principle, for protecting and improving the urban drainage ways for recreational and other beneficial uses. The specific economic and social costs which will be required to assure such protection were not clearly and fully identified prior to the NURP study, however, and the final level of public support will only be known after those costs have been determined and a final management plan proposed.

PROJECT DESCRIPTION

A. Major Objectives

The overall objective of NURP project activities is to complete the technical, institutional, and financial groundwork necessary for effective implementation of the ordinances, policies, plans and specific programs developed in conceptual form during the earlier 208 assessment of urban runoff problems in the Eugene/Springfield area. The specific objectives are:

1. To complete inventories of beneficial uses, problems and development potentials for all urban storm drainages, provide maps and develop basin goals and plans, and assure protection of critical areas through adoption of appropriate Comprehensive Metropolitan Plans by appropriate planning agencies and public works departments;
2. To refine potential Best Management Practices (including analysis of costs and effectiveness of alternative strategies), and provide each jurisdiction with general basin, and problem-specific strategies suitable for adoption (including strategies for critical problem areas or significant runoff hazards);
3. To conduct pilot studies to adapt BMP's operationally to local situations, and explore innovative, passive, low energy or low cost control alternatives (street and site maintenance modifications, control ordinances, and instream treatment systems);
4. To perform financing studies to develop a funding base for runoff management programs (with a major focus on exploration of a "user charge" financial base for support of a management plan);
5. To develop plans for coordination of existing ordinances for the control of industrial, construction, commercial and residential site runoff, provide brief cost-benefit analysis on effective ordinance enforcement and develop guidance to assist appropriate jurisdictions in enlarging funding for ordinance enforcement;
6. To conduct data gathering programs to define more accurately the following concerns: toxic chemicals runoff (heavy metals) chronic receiving stream impacts, the relationships between specific beneficial uses and quality constraints, winter peak and spring flow quality and loading, effectiveness of natural treatment systems, and pilot study evaluations;
7. To recalibrate the previously used STORM II or SAM model of runoff/rainfall relationships on key channels, use it to predict problems associated with peak flow and spring runoffs, and assess costs of structural flow management options;
8. To provide accurate and up-to-date information on runoff control problems and strategies to public works and planning departments, public interest groups, and special interest (e.g., industrial concerns) groups so as to involve them all in the development of goals and plans for the preservation of beneficial uses of urban waters;

9. To evaluate the impacts of storm runoff pollution on existing and proposed beneficial uses of the Amazon Creek and "Q" Street Channel systems and the quality impacts of proposed diversions on source and receiving streams.

B. Methodologies

To accomplish the above objectives, a broad spectrum of activities were planned and are now nearing completion. All urban drainage basins were inventoried, and mapped on the basis of currently availalbe information. Maps include land use, vegetation, zoning and planning designations, soils, hydrologic control points, major impervious zones, benefical uses and problem areas. The maps are in a format suitable for Comprehensive Metropolitan Plans.

SNYOP was combined with sub-basin rain gage data to analyze storm trends but found not to be effective as a defining tool in the Northwest due to the length of storms and their lack of intensity. Wetfall/dryfall and rainfall samples from stations located strategically around the metropolitan area, are regularly collected and analyzed. Background and storm sampling for flow and numerous water quality parameters have been conducted for more than a year at both control and loading sites.

Pilot studies of sediment traps, vegetation management, industrial site runoff management (straw bale oil/grease trap) and street sweeping/street maintenance have been conducted to determine their effectiveness and feasibility as relatively low-cost, easy-maintenance control measures. Priority pollutant sampling has been carried out at two sites. In-stream water quality impacts were assessed by means of an invertebrate and periphyton analysis at the vegetation site.

Analysis of land development ordinances in both Eugene and Springfield is aimed at evaluating the effectiveness of existing ordinances in controlling pollution from erosion, track-out and increased runoff, the enforceability of such ordinances and the extent to which they allow fixing the responsibility for such problems on the land developers. Major emphasis has been given to preparation of a detailed financial management plan by a financial consultant which includes cost/budget breakdowns for both cities in terms of current revenues and sources, cost projections for various runoff management programs and recommended program funding options for each city specifically designed to incorporate water quality enhancement and protection costs.

C. Monitoring

Twenty-six (26) sampling sites were established throughout the Eugene/Springfield Metropolitan area and for the most part have been sampled under both storm and base flow conditions for flow and various water quality parameters. Water quality samples were taken manually and flows were measured for the most part by the use of stream gages.

Sixteen (16) of the sampling sites were used to collect in-stream water quality data for one or more of several purposes: to provide additional data needed to refine the STORM II or SAM Model, to assess the impact of urban runoff upon Willamette River water quality, to assess the impact of street cleaning frequency and to assess the impact of industrial/commercial/construction activity upon run-off quality.

Three (3) of the sampling sites have been used to evaluate the straw bale oil/grease trap installed in an open ditch draining a wood products industrial site, with two sites located above the control site and one below it. Two (2) of the sites were used in the spring of 1981 for priority pollutant sampling. Two (2) sites have been utilized to evaluate the performance of a sediment trap in a relatively newly developed part of Eugene upstream from the commercial/industrial section of the city. Three (3) sites have been used to assess the impacts of natural vegetation and alternative vegetation management techniques upon water quality.

The parameters for which the samples were analyzed included total and suspended solids, pH, conductance, turbidity, hardness, alkalinity, temperature, BOD, COD, Nitrogen, Phosphorus, lead, zinc, chromium, mercury, copper, iron, arsenic, coliforms, bio-indicators (periphyton and invertebrates), flow and pesticides (as needed).

Controls

The controls which were evaluated as part of the Eugene/Springfield NURP were vegetation treatment and management, sedimentation traps, street sweeping, land development ordinances and straw bale oil/grease traps.

APPENDIX H

THE OFFICE OF RESEARCH AND DEVELOPMENT'S STORM AND COMBINED SEWER PROGRAM

APPENDIX H
INTRODUCTION

Over the past 15 years, much research effort has been expended and a large amount of data has been generated on the characterization and control of stormwater discharges and combined sewer overflows (CSO), primarily through the actions and support of the U.S. Environmental Protection Agency's (EPA) Storm and Combined Sewer Control Research and Development (SCS) Program.

The program originated in 1964 under the EPA predecessor organization, the U.S. Public Health Service, and has been supported by U.S. Public Laws (PL) since 1965 (presently by the "Federal Water Pollution Control Act Amendments of 1972," PL 92-500 and the "Clean Water Act of 1977," PL 95-217).

The purposes of the program are to quantify urban storm and CSO pollution problems and develop countermeasure controls.

These urban wet-weather pollution control advancements are and can be used by those municipal and consulting engineers and planners concerned with area-wide/city-wide pollution control plans, strategies, and facilities required for the management and control of urban stormwater runoff.

Because it is nearly impossible to segregate benefits and strategies of urban stormwater runoff pollution control from drainage, flood, and erosion control, multipurpose analyses and control are stressed.

There have been over 250 projects under the program on urban stormwater runoff and CSO, but only urban stormwater runoff projects, the CSO projects which directly relate to urban stormwater runoff, and the basic program direction will be highlighted. The products will be divided into the following areas: (1) Problem Definition, (2) User Assistance Tools (instrumentation and models), and (3) Management Alternatives.

PROBLEM DEFINITION

Characterization

Urban stormwater runoff is a significant source of pollution, having suspended solids concentrations equal to or greater than untreated sanitary wastewater, and 5-day Biochemical Oxygen Demand (BOD_5) approximately equal to secondary effluent.

Under certain conditions, urban stormwater runoff can govern the quality of receiving waters, regardless of the level of treatment of dry-weather flow provided (1).

Table 1 shows average pollutant concentrations in urban stormwater runoff. The samples were taken in various parts of the country, from diverse land use, during different seasons, and during dissimilar rainfall events. The average pollutant concentrations shown in the the table indicate an order of magnitude of the stormwater runoff problem and the ranges indicate the wide variations in concentrations that may be anticipated.

TABLE 1. POLLUTANT CONCENTRATIONS IN URBAN STORMWATER RUNOFF (2)

	Average pollutant concentrations, mg/L									
City	TSS	VSS	BOD_5	COD	Kjeldahl nitrogen	Total nitrogen	Phosphorus	OPO_4-P	Lead	Fecal coliform[a]
Atlanta, Georgia	287	---	9	48	0.57	0.82	0.33	----	0.15	6 300
Des Moines, Iowa	419	104	56	---	2.09	3.19	0.56	0.15	----	----
Durham, North Carolina	1 223	122	--	170	0.35	----	0.82	----	0.46	230
Knoxville, Tennessee	440	---	7	98	1.9	2.5	0.63	0.30	0.17	23 300
Oklahoma City, Oklahoma	147	---	22	116	2.08	3.22	1.00	1.00	0.24	40 000
Tulsa, Oklahoma	357	---	12	86	0.55	----	----	0.38	----	420
Santa Clara, California	224	73	23	147	----	5.8	0.23	----	0.75	----
Pullach, Germany	158	53	11	125	----	---	----	----	----	----
Average (not weighted)	415	88	20	113	1.41	3.11	0.62	0.46	0.35	13 500
Range	147-1 223	53-122	7-56	48-170	0.57-2.09	0.82-5.8	0.33-1.00	0.15-1.00	0.15-0.75	230-43 000

a. Organisms/100 mL.

From 40-80 percent of the total annual organic loading entering receiving waters from a city is caused by sources other than the treatment plant (3). During a single storm event, 95 percent of the organic load is attributed to wet-weather flow sources which include urban stormwater runoff and CSO. About 70 lb/ac/yr (75 kg/ha/yr) of BOD in urban stormwater runoff discharges contribute 45 percent of the annual BOD load if secondary treatment is provided for the dry-weather flow (4). Heavy metals in urban stormwater runoff have been investigated at numerous sites across the United States. The data have been condensed and are shown in Table 2.

584

TABLE 2. HEAVY METAL CONCENTRATIONS IN URBAN STORMWATER RUNOFF (4, 5)

Metal	Concentration Ranges in Urban Stormwater Runoff, μg/l*
Antimony	20 - 60
Arsenic	0.2 - 100
Beryllium	1.0 - 4.0
Cadmium	0.6 - 9000
Chromium	4 - 10000
Copper	2 - 700
Lead	3 - 5000
Mercury	0.1 - 60
Nickel	9 - 400
Selenium	0.8 - 10
Silver	2 - 10
Thallium	0.2 - 10
Zinc	10 - 780

*Includes grab and flow-weighted samples

Bacterial contamination of separate stormwater is two to four orders greater than concentrations considered safe for water contact. Excess concentrations of pathogenic organisms in urban stormwater runoff will hinder water supply use, recreational use and fishing/shell fishing use of the receiving water (6,7,8). The frequency of occurrence of human pathogenic organisms in storm flow was found to relate to cross contaminations from sanitary sewage (9).

Characterization: Products

Past characterization studies for storm flow provide a data base for pollutant source accumulation, and hydraulic and quality loads. A computerized data base and retrieval system, especially useful for urban stormwater runoff pollution problem assessment efforts, containing screened data for model verification and study area data synthesis, has been developed (10).

Receiving Water Impacts

Approximately 50 percent of the stream miles in this country are water quality-limited and 30 percent of these stream lengths are polluted to a certain degree with urban stormwater runoff (3), which contributes oxygen demanding material, toxic organics, and metals to the water and sediment (11, 12, 13, 14, 15).

Dissolved Oxygen Depletion. The SCS Program has had only partial success in finding direct urban storm flow generated receiving water impacts employing the conventional dissolved oxygen (DO) parameter. The problem appears to be in the application of conventional dry-weather monitoring in unsteady-state flow regimes caused by storms. Based on a comparative analysis of wet vs. dry-weather oxygen demanding substance loads as shown in Table 3, there remains a high potential for adverse impacts to occur in receiving waters (1, 11). The Program has been more successful in sediment analysis than in water column analysis for DO depletions. Direct evidence has been obtained from the Milwaukee River project (16) of how a distrubed benthos depletes DO from the overlying waters.

Nutrients. The discharge of materials, such as phosphorous, which fertilize or stimulate excessive or undesirable forms of aquatic growth can create significant problems in some receiving water systems. Overstimulation of aquatic weeds or algae (eutrophication) can be aesthetically objectionable, cause dissolved oxygen problems, and in extreme cases, can interfere with recreational use and create odors and heavy mats of floating material at shorelines (1,2).

TABLE 3. NATIONAL ANNUAL URBAN WET- AND DRY- WEATHER FLOW BOD_5 AND COD LOAD COMPARISONS* (4)

TYPE	PERCENT OF DEVELOPED AREA	ANNUAL DWF**		ANNUAL WWF**		PERCENT WWF	
		BOD_5 MIL LB.	COD MIL LB.	BOD_5 MIL LB.	COD MIL LB.	BOD_5	COD
COMBINED	14.3	340	910	880	2840	72	76
STORM	38.3	710	1890	440	2500	38	57
UNSEWERED	47.4	310	830	360	2250	54	73
TOTALS	100	1330	3630	1640	7390	55	67

*ASSUMING

	BOD_5 (MG/L)	COD (MG/L)
CSO	100	300
URBAN STORMWATER	20	125
DRY-WEATHER	30	80

**LB = 0.454 KG

In Lake Eola, Florida, urban stormwater runoff was found to be the sole source of lake degradation (17). Urban stormwater runoff is the only flow entering the lake. Phosphorous concentrations in the runoff were found to significantly increase algal productivity.

Biota Impacts. An assessment of the environmental impact of urban stormwater runoff requires a comprehensive in-depth analysis of water quality and the biological community in the receiving stream.

In San Jose, California (15), sampling showed that the nonurbanized section of Coyote Creek supported a diverse population of fish and benthic macroinvertebrates as compared to the urbanized portion which was completely dominated by pollution tolerant algae, mosquito fish, and tubificid worms. Figure 1 shows this point. Similar results were found in the Lake Washington Project (18) where bottom organisms (aquatic earthworms) near storm outfalls were more pollutation tolerant relative to those at a distance from these outfalls.

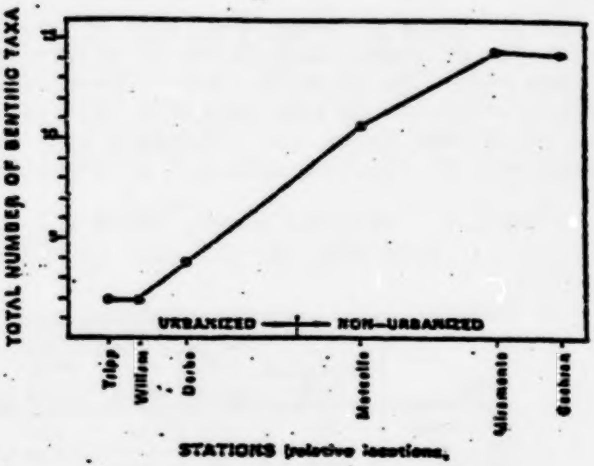


Figure 1. Abundance of Benthic Taxa: Coyote Creek, San Jose, California

Toxicity. Over the years, the SCS Program has compiled data which have shown that a significant amount of toxic substances, including priority pollutant heavy metals, and organics (most of petroleum origin) exist in urban stormwater runoff (1, 2).

Typically, heavy metal concentrations in urban stormwater runoff are in excess of the proposed EPA water quality criteria for aquatic life protection even with many receiving water dilutions (4). Many of these metals and other toxics are associated in varying degrees with particulates.

Sediment samples in Lake Washington (18) were analyzed for metals, organics, phosphorus, chlorinated hydrocarbons and PCB's. Composite indices, to assess wet-weather impacts, were up to 16 times the minimum background control value. Also, pesticide levels in sediments along the Seattle shoreline of Lake Washington were up to 37 times background concentrations.

In Coyote Creek (15), urban sediment compared to non-urban sediment contained higher concentrations of lead, arsenic, BOD_5 and orthophosphates. Significantly greater concentrations of high molecular weight hydrocarbons and oxygenated compounds were also found in the urban samples. Lead and zinc concentrations in urban samples of algae, crawfish and cattails were two to three times greater than in non-urban samples.

In fiscal year 1981, the SCS Program entered into a wet-weather priority pollutant study with the EPA Office of Water Regulations and Standards. The objectives of this project are to determine the magnitude of toxic pollutants in urban stormwater runoff, CSO, and combined sewer sediment.

An ongoing project involves screening urban stormwater runoff and CSO for bacterial mutagens using the Ames test. Positive results have been obtained from a number of samples (19).

It is strongly suspected that for many of these contaminants, treatment or control will be needed in order to satisfy effluent guidelines and water quality standards.

Erosion/Sediment Impacts. Urbanization causes accelerated erosion and raises sediment yields two to three orders of magnitude. At the national urbanization rate of 4,000 acres/day, erosion and sedimentation are major environmental problems (20, 21, 22, 23).

Solution Methodology Products

The state-of-the-art (SOTA) text (24) on urban stormwater technology is an excellent guide for planners and engineers. It organizes and presents more than 100 completed program projects. Also published are reports on stormwater management planning (25, 26), an updated SOTA, which includes guidelines for city-wide wet-weather pollution control (2), case histories report on urban stormwater management and technology (20), and a soon to be published design manual on storage/sedimentation for control of urban stormwater runoff and CSO (27).

A Program film on full-scale control technologies is available. Program seminar proceedings with themes of planning, design, operation, and costs have been published (28). Separate engineering manuals are available for storm flowrate determination, storm flow sampling, storm sewer design, and for conducting stormwater studies (29, 30, 31, 32, 33, 34). All of these documents are valuable for planning, design, evaluation, control and enforcement.

A cost estimating manual has been published for construction and operation of storage and treatment devices (35). Other manuals are available for deicing pollution (36, 37, 38, 39) and erosion control (40, 41, 42, 43, 44, 45). The SOTA document on particle size and settling velocity (46) offers significant information for solids treatability and their settlement in receiving waters, an important area always overlooked during planning and design. Endeavors to study direct receiving water impacts, along with model verification, will lend credence to the implementation of storm flow impacts.

USER ASSISTANCE TOOLS

Instrumentation

Storm flow measurement is essential for process planning, design, control, evaluation, and enforcement. Sampling devices do not provide representative aliquots, and in-line pollutant monitoring capabilities are needed. Conventional flow meters apply to steady-state flows and not to the highly varying storm flows.

Instrumentation: Products. Flowmeters, including nonintrusive, electromagnetic, ultrasound, and passive sound types, have been developed to overcome adverse storm conditions (33, 48, 49, 50, 51). A prototype sampler for capturing representative solids in storm flow has also been developed and a design manual is available (52). This manual lead to design changes by sampler manufacturers. Instantaneous in situ monitoring devices for determination of suspended and total organic carbon have been developed and demonstrated (53, 54). Because storm flow conditions are extremely adverse, these manuals and instruments are useful for monitoring all types of flow (32).

Models

Simulation Models. Models are needed to predict complex dynamic response to variable runoff phenomena. Models are categorized into: (1) simplified, for preliminary planning, (2) detailed, for planning and design, and (3) operational, for supervisory control.

The Storm Water Management Model (SWMM) provides a detailed simulation of stormwater quantity and quality during a storm event. Its benefits for detailed planning and design are widely accepted, but for certain users it may be too detailed. Consequently, four levels of evaluation techniques (from simple to complex) that can be worked together have been developed.

Planning/Design Models. There are four levels of Planning/Design Models.

Level I. The Level I procedure was derived from a nationwide assessment (55). The nationwide assessment contains data on: (1) land use, (2) drainage system types, (3) runoff volumes and pollutant quantities, and (4) costs and cost-effective control strategies for urban areas, state and EPA Regions. The information can be used for preliminary assessment and planning, and determining national cost requirements.

In Level I, the "desktop" procedure (56) estimates the quantity and quality of urban runoff. Equations have been developed to estimate pollutant loads as functions of land use, sewer system type, precipitation, population density, and street sweeping. Equations are also provided for dry and wet-weather flow quantification.

A method for evaluating the optimal storage-treatment mix and associated costs has also been developed in Level I. Procedures for comparing tertiary with stormwater treatment and savings from integrated dry and wet-weather flow management from combined and separate areas (56) and from integrated nonstructural management practices (57) are included.

Level II. Level II involves a flexible and inexpensive simplified continuous model for planning and preliminary sizing of facilities. The model can screen an entire history of rainfall records and is especially valuable in sizing storage facilities based on storm return periods and available in-line capacity. A user's manual is available (58). Other Level II models are ABMAC (59), and EPAMAN (60).

Level III. Level III is a more refined continuous model using Storage, Treatment, Overflow Runoff Model (STORM) and continuous SWMMM (61) for providing flow time routing and allowing for continuous receiving water impact analyses (62). A few thousand statements are involved as compared to a few hundred for Level II. The continuous SWMM user's instructions are available in draft form (62), and the computer program is available. Another Level III (and IV) model is QQS (63, 64).

Level IV. The first three levels relate to planning and involve relatively large time steps and long stimulation time. Data requirements and mathematical complexity are relatively low.

Design models require short time steps and simulation times for detailed prediction of a single storm event, and their data needs are extensive. They provide complete flow and pollutant routing and prediction through the runoff system and into receiving waters, and can show the exact manner in which abatement procedures affect hydraulic and pollutant loads. These models and user's manuals are available (62, 63, 64, 65, 66). The program has expanded SWMM into an Urban Water Management Model which integrates both dry and wet-weather flow analyses including sludge handling (62).

Operational Models. Operational models produce control decisions during a storm. Rainfall is entered from telemetered stations and the model predicts system response a short time into the future and augments control settings. We have demonstrated supervisory control models, in combined sewer systems, in Detroit (30), Minneapolis (67), and Seattle (68, 69).

Other Products. Othe simulation model products include a dissemination and user's assistance capability (70), and a short course and course manual (71, 72). Of particular note is the SOTA assessment document on 18 models for urban runoff management (73). The document presents advantages and limitations of each model and a comparison to aid in model selection.

MANAGEMENT ALTERNATIVES

Wet-weather flow control is grouped into three management alternatives. First, the decision must be made where to attach the problem: (1) at the source by land management, (2) in the collection system, or (3) with separate storage basisn. We can remove pollutants by treatment and by employing integrated systems combining control and treatment. Second, there is the decision of the degree of control necessary. Third, there is the need for assessing impacts, and ranking the problem with other needs. Proper management alternatives can only be made after conducting a cost-effective analysis involving goals, values, and hydrologic-physical system evaluations.

Land Management

Land management includes all measures for reducing urban and construction site stormwater runoff and pollutants before they enter the downstream drainage system.

Structural/Semistructural Control

On-Site (Upstream) Storage. On-site or upstream refers to short term detention or long term retention of stormwater runoff prior to entry into the drainage system. Design can provide for benefits in aesthetics, recreation, recharge, irrigation, or other uses (27).

Successful low-cost dual-use variations of detention are ponding on parking lots, plazas, recreation and park areas, and rooftops. Apparent economic benefits are derived from surface ponding for flood protection over a conventional sewer project. Additional benefits are realized when the multipurpose benefits of erosion and pollution control from these basins are considered.

Porous Pavements. The use of an open graded asphalt-concrete pavement during pilot tests has allowed over 70 in./hr of stormwater to flow through. The cost is comparable to conventional pavement. Clogging resistance and filtered water quality evaluations have been made. Porous pavement can be important in preserving natural drainage and decreasing downstream drainage and pollution control facility requirements. A feasibility report is available (74) and the program has recently completed evaluating a porous pavement parking lot north of Houston at the new planned community--The Woodlands (8, 75). Porous pavement was recently demonstrated for CSO control in Rochester, New York (76).

Results of the Rochester study indicated:

1. Peak runoff rates were reduced by as much as 84 percent.

2. The pavement, which was subject to 100 freeze/thaw cycles in the laboratory, showed no observable structural degradation. In addition, the water drained through the pavement without problems during the winter.

3. Through observations and flow monitoring, it was determined that the structural integrity of the porous pavement installed, where heavy load vehicles were parked, was not impaired.

4. Clogging did result from runoff carrying a heavy sediment load. Clogging during the test study was relieved through cleaning.

A project in Austin, Texas is comparing the runoff and water quality characteristics of porous asphalt cement pavement to other kinds of conventional (concrete, gravel, grass, conventional asphalt with a drainage system, conventional asphalt with a peripheral drainage trench), and experimental (grass and concrete lattice-type pavement) porous paving materials. The overall objective is to develop design criteria for potential porous pavement construction. Phase I of this project has been completed (77). It consisted of accumulating and condensing all available design, construction, and operational data for existing porous pavement areas to develop preliminary design and operational criteria.

Solids Separation. Sediment basins trap and store sediment to conserve land and prevent excessive siltation. If designed properly, these basins remain after construction for on-site storage.

Because a significant portion of solids remain suspended and cannot be treated by sedimentation, special devices for fine-particle removal are required. A project developed a SOTA on fine-particle removal (78), and also evaluated a tube settler and a disc screen (79).

The swirl concentrator has been developed to control the impacts of erosion and to remove settleable solids at much higher rates than sedimentation (80, 81, 82, 83).

Nonstructural

Surface Sanitation. Reduction of litter and debris, and both street repair and street sweeping can minimize pollutants washed off by stormwater (84, 85, 86). It may well be cheaper to remove solids by street sweeping than from the sewer system.

Street sweeping results are highly variable. Therefore, a street sweeping program for one city cannot be applied to other cities, unless the program is shown to be applicable through experimental testing. This may be seen when comparing street sweeping test results from San Jose, California, and an ongoing project in Bellevue, Washington (87, 88).

Street cleaning not only affects water quality; but has multiple benefits including improving air quality, aesthetic conditions, and public health. Since street cleaning alone will probably not ensure that water quality objectives are met, a street cleaning program would have to be incorporated into a larger program of "best management practices," and/or downstream treatment. A user's manual on cost-effective comparisons of street cleaning and sewer flushing with downstream treatment is available (57).

Chemical Use Control. Reduction in the indiscriminate use of chemicals such as fertilizers and pesticides, and the mishandling of oil, gasoline, and highway deicing chemicals will reduce stormwater runoff pollution (36, 37, 38, 39).

Urban Development Resource Planning. The goal of urban development resources planning is a macroscopic management concept to prevent problems from shortsighted planning. A new breed of planner is required to consider the new variables of land usage, population density and total wet and dry-weather runoff control as they integrate to affect water pollution. A simple land planning model has been developed to encompass the new variables and control options (21).

Use of Natural Drainage. Traditional urbanization upsets the water balance by replacing natural infiltration areas and drainage with impervious areas. The impact is increased stormwater runoff, decreased infiltration to the ground water and increased channel erosion and transport of pollutants to the stream. Promoting natural drainage will reduce drainage costs and pollution, and enhance aesthetics, ground-water supplies, and flood protection.

A project in Houston, Texas focused on how a "natural drainage system" integrates into a reuse scheme for recreation and aesthetics (8, 75). Runoff flows through vegetative swales and into a network of wet-weather ponds, strategically located in areas of porous soils. This system retards the flow of water downstream preventing floods by development, and enhances pollution abatement.

The ability of marsh/wetlands to remove pollutants from stormwater has been demonstrated in Wayzata, Minnesota and Palo Alto, California (89, 90). A SOTA manual was developed on best vegetative practices and wetlands utilization for removing pollutants from urban stormwater runoff (91). It involves the review and analysis of scientific investigations and other basic literature sources concerning biochemical processes, pollutant uptake properties and tolerances of various marsh and upland vegetation types. Additionally, a detailed review and analysis was made of vegetative and hydraulic/hydrologic practices relative to the management of wetland and upland ecosystems for treatment of urban stormwater runoff.

Nonstructural Erosion/Sedimentation Control

Nonstructural soil conservation practices such as cropping, mulching, chemical soil stabilization, and berming may be relatively inexpensive (22,23).

Erosion/Sediment Control: Products

An audiovisual training program with workbook and instructor's manual (41,42) has been developed for the local land developer, inspector, and job foreman, and is designed to directly support the State of Maryland's published "Standards and Specifications for Erosion and Sediment Control." As state and local agencies move toward setting standards for control, the need for this type of training program becomes urgent. Several erosion control techniques were evaluated in the Piedmont Region of the United States and in the Lake Tahoe Region of California (22, 23).

Drainage System Controls

Drainage system control pertains to management alternatives concerned with urban stormwater runoff collection, interception, and transport. This includes improved maintenance and design of catchbasins, elimination of sanitary and industrial wastewater cross connections, in-pipe and in-channel storage, and remote flow monitoring and control. The emphasis is on optimum use of existing facilities. Because use of the existing system is employed, the concepts generally involve cost-effective, low structurally intensive control.

Catchbasins. A catchbasin is defined as a chamber or well, usually built at the curbline of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow. An optimized catchbasin configuration and geometry has been developed by hydraulic modeling (92).

In a project conducted in the West roxbury section of Boston (93), three catchbasins were cleaned, and subsequently, four runoff events were monitored at each catchbasin. Average pollutant removals per storm are shown in Table 4.

-93

TABLE 4. POLLUTANTS RETAINED IN CATCHBASINS

Constituent	% Retained
Suspended Solids	60-97
Volatile Suspended Solids	48-97
COD	10-56
BOD_5	54-88

Catchbasins must be cleaned often enough to prevent sediment and debris from accumulating to such a depth that the outlet to the sewer might become blocked. The sump must be kept clean to provide storage capacity for sediment, and to prevent resuspension of sediment (92). It is also important to clean catchbasins to provide liquid storage capacity.

Sewer System Cross Connections. Sanitary and industrial wastewater cross connections are a significant reality, which, in effect, make the separate storm sewer a combined sewer. Where cross connections are suspected, investigations should be made of the drainage network, using screening/mass balance techniques, to determine the sources of sanitary or industrial contamination. Once the sources have been isolated, an analysis will bave to be made to determine whether corrective action at the sources, or downstream treatment, is most feasible.

Flow Routing. Another drainage system control method is in-pipe, and in-channel storage and routing to maximize use of existing drainage system capacity (94). The general approach uses remote monitoring of rainfall, flow levels, and sometimes quality, at selected locations in the network, together with a centrally computerized console for positive regulation. As previously mentioned, this concept has proved effective for combined sewers in Detroit, Minneapolis, and Seattle (30, 67, 68, 69), and the technology is transferable to storm sewers.

Regulators-Regulators/Concentrators. To protect receiving water from the effects of stormwater discharges, conventional static regulators used for CSO control (95) can be installed in separate storm sewers to divert stormwater to either a sanitary interceptor, or to a storage tank.

The dual functioning swirl flow regulator/solids separator has shown outstanding potential for simultaneous quality and quantity control. At present, there is a strong need to develop and have a reserve of control hardware for urban runoff control and to effectively reduce the associated high cost implications for conventional storage tanks, etc. It is felt that the swirl/helical type regulators, previously applied only to CSO, can also be installed on separate storm drains before discharge and the resultant concentrate flow can be stored in relatively small tanks, since concentrate flow is only a few percent of the total flow. Stored concentrate can later be directed to the sanitary sewer for subsequent treatment during low flow or dry-weather periods, or if capacity is available in the sanitary interceptor/treatment system, the concentrate may be diverted to it without storage.

These methods of stormwater control (illustrated in Figure 2) may be more economical than building huge holding reservoirs for untreated runoff, and offer a feasible approach to the treatment of separately sewered urban stormwater (96, 97, 98, 99, 100, 101, 102).

A project in West Roxbury, Massachusetts represents the first trial on storm water (102). This project is receiving joint sponsorship from the Nationwide Urban Runoff Program (NURP), the State and the SCS Program. Full-scale field demonstrations of the swirl and helical bend devices have been, or are currently being conducted. Since non-point control may soon move into the implementation phase, it is important to demonstrate these units on a comparative basis.

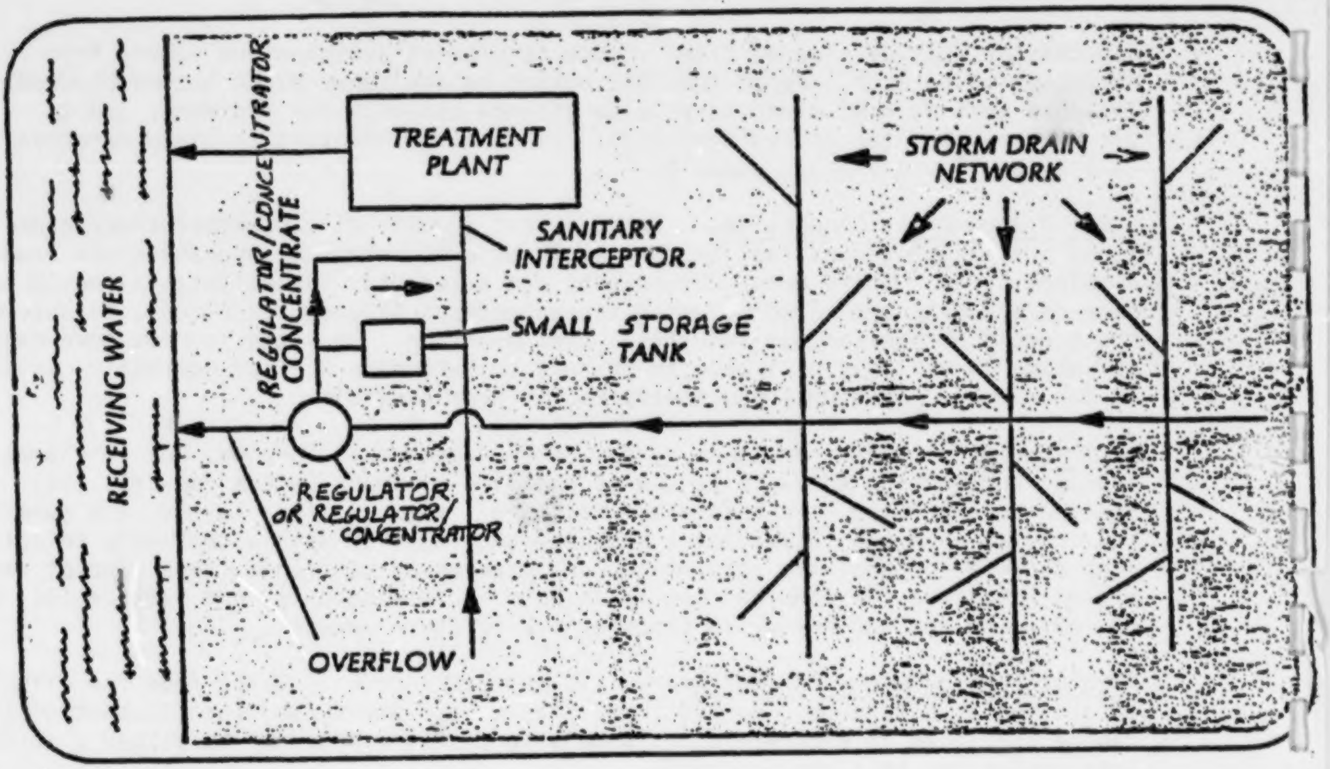


Figure 2. Regulator-Regulator/Concentrator Urban Stormwater Control Devices

Storage

Because of the high volume and variability associated with urban stormwater runoff, storage is considered a necessary control alternative. Storage must be considered at all times in system planning, because it allows for maximum use of the existing dry-weather treatment plant and drainage facilities, optimum economic sizing of new stormwater treatment facilities, and results in the lowest cost control system, for all cases. The runoff is stored until the downstream system can accept the extra volume. At that time, it is discharged.

Storage basins can provide the following advantages: (1) they respond without difficulty to intermittent and random storm behavior, (2) they are not upset by water quality changes, and (3) they are simple in structural design and operation.

35

Storage concepts that have been investigated for CSO, but can be used for urban stormwater runoff, include the conventional concrete holding tanks and earthen basins (103, 104, 105, 106, 107, 108), underwater containers (109, 110, 111), gravel packed beds (112), natural and mined underground formations (113, 114, 115), and existing sewer lines (30, 67, 68, 69).

Treatment

Due to considerable hydraulic variation, and unpredictable shock loading effects during storm events, it has been difficult to adapt existing treatment methods to storm-generated flows, especially the microorganism-dependent biological processes. The newer physical/chemical treatment techniques have shown more promise in overcoming these adversities. To reduce capital investments, projects have been directed towards high-rate operations approaching maximum loading.

Wet-weather flow treatment methods that have been investigated, and that can be adapted to treat urban stormwater runoff, are mainly physical/chemical treatment (116-128).

Disinfection

Because disinfectant and contact demands are great for storm flows, research has concentrated on high-rate applications by mixing and more rapid oxidants, i.e., chlorine dioxide, ozone and ultraviolet, and on-site generation (6, 129, 130, 131, 132, 133). Although research has centered around CSO disinfection, similar high-rate systems may be necessary for certain urban stormwater runoff applications where runoff is impacting high-value contact recreation waters.

System Integration

Dual-Use Treatment. A process designed to treat only wet-weather flow may not be in operation for long stretches of time. This is less cost-effective than a process designed to treat both dry and wet-weather flows. Therefore, it is important to pursue the investigation of dual-use treatment technologies.

The Program has demonstrated the dual use of high-rate trickling filters (134), and high-rate filtration (124). On a pilot scale, powdered activated carbon absorption/alum coagulation has been evaluated (128).

Urban Stormwater Reuse. Previous projects have evaluated the reuse of urban stormwater runoff for aesthetic, recreational, and subpotable and potable water supply purposes (137, 138, 139). In Mount Clemens, Michigan, a series of three "lakelets" have been incorporated into a CSO treatment-park development. Treatment is being provided so that these lakes are aesthetically pleasing and allow for recreation and reuse for irrigation (140).

TECHNOLOGY TRANSFER

Technology transfer covers the formal dissemination of program findings. To date, the SCS Program has published over 250 reports (141), concentrating on "user" type documents.

RECOMMENDATIONS FOR THE FUTURE

Receiving Water Impacts

Ties between receiving water quality and stormwater discharges must be clearly established and delineated. Quantification of the impairment of beneficial uses and water quality by such discharges is a major goal. Project results indicate the potential for significant impact to receiving waters of wet-weather flows. Control of runoff pollution can be a viable alternative for maintaining receiving water quality standards. However, the problems found seem to be site specific in nature. Therefore, site specific surveys are required. Based on results from these surveys, control may be warranted.

Toxics Characterization and Control/Treatment

Results from a limited in-house effort indicate that urban stormwater runoff contains significant quantities of some priority pollutants.

An important area requiring further work is the comparison of priority pollutant concentrations and quantities in wet-weather flow and their respective dry-weather flow values. Additional investigation of the significance of concentrations and quantities of toxic pollutants with regard to their health effects is required. A need exists to evaluate the removal capacity of alternative treatment technologies for these toxics and to compare their effectiveness with estimated removal needs to meet water quality goals.

Sewer System Cross Connections

Investigations have shown that sanitary and industrial contamination of separate storm sewers is an extensive nationwide problem. In other words, a significant number of separate stormwater drainage systems function as combined sewer systems. Therefore, a nationwide effort on both Federal and local levels, to alleviate the pollution impacts from discharges of these systems is required. It is better to classify such bastardized drainage systems as combined systems for pollution control priorities.

Integrated Stormwater Management

The most effective solution methodology for wet-weather pollution problems must consider: (1) Wet-weather pollution impacts in lieu of blindly upgrading existing municipal plants, (2) structural versus non-structural techniques, (3) integrating dry and wet-weather flow systems to make maximum use of the existing drainage system during wet conditions and maximum use of wet-weather control/treatment facilities during dry-weather, and (4) the segment or bend on the percent pollutant control versus cost curve in which cost differences accelerate at much higher rates than pollutant control increases, although load discharge or receiving water requirements will dictate, ultimately, the degree of control/treatment required.

Flood and erosion control technology must be integrated with pollution control, so that the retention and drainage facilities required for flood and erosion control can be simultaneously designed for pollution control. If land management and non-structural techniques are maximized and integrated, there will be less to pay for the extraction of pollutants from storm flows in the potentially more costly downstream plants.

The optimal solution is going to come from multi-use, multi-purpose facilities offering multi-benefits. Up to now, sotrmwater management has usually meant flood and drainage control. In order to make wet-weather pollution control economical, ways have to be initiated to utilize flood control techniques for multi-purpose benefits such as pollution control, erosion control and reuse (irrigation, fire fighting, ground-water, recharge, etc.). When ground-water recharge is an objective, pollutant removal properties of the soil profile must be taken into account.

A modification to the CSO philisophy can be utilized by older and/or built-up cities with so-called separate stormwater drainage systems. In effect, they probably have CSO because of the proximity to sanitary and industrial sources and the potential for cross connections. Generally, they also have a lot of sanitary lines, in close proximity to stormwater lines, going to sewage treatment plants. A solution is to try to establish the types of control used for CSO which allow bleed-ins and/or underflow to the sewage treatment plant during low flow.

Another topic is the integrated approach to new development planning and stormwater management. The following questions have to be answered: Should a separate or combined sewer system be built? Under what conditions should we opt for either one? New design concepts need to be employed for integrated stormwater management as per above. Zoning and land use distributions need to be considered so that buffer zones which will lessen stormwater runoff quantity and quality impacts can be developed. Other topics which need to be considered include:

1. Chemical use criteria (such as fertilizer, deicing salt, and chemical stockpiling restrictions).
2. Fines for dumping oil in drains.
3. A more immediate ban on leaded gasoline.
4. Further considerations on highway salt misuse.

Institutional Socio/Economic Conflicts

Some of the most promising opportunities for cost effective environmental control are multi-purpose in nature. However, there are institutional problems that hinder their implementation. First, the autonomous Federal and local agencies and professions involved in flood and erosion control, pollution control, and land management and environmental planning must be integrated at both the planning and operation levels. Multi-agency grant coverage must be adequate to stimulate such an approach. For example, EPA would have to join with the Corps of Engineers, Soil Conservation Service, Department of Transportation, and perhaps other Federal agencies as well as departments of pollution control, sanitation, planning, and flood control at the local level.

Another problem is that construction grant incentives are geared towards structurally intensive projects which may counter research findings in the area of optimal solutions.

Optimized wet-weather pollution control usually involves a city-wide approach including the integration of structural as well as low-structural controls. The low-structural measures more labor intensive. Construction grant funding does not presently address this expense and accordingly muncipalities are discouraged from using them. An example of this is the Boston Metropolitan District Commission's reluctance to incorporate sewer flushing technology for the very reasons mentioned.

CONCLUSIONS

In general, on a mass basis toxics, bacteria, and oxygen demanding, suspended, and visual matter in urban stormwater runoff are significant. Ignoring the problem because it seems to be too costly to solve by conventional methods, such as separate facilities for dry-weather flows, flood, and wet-weather pollution control is the only way which is going to be feasible, economical and, therefore, acceptable. Potentially tremendous "bangs for the bucks" can be derived from wet-weather pollution control research fostering integrated solutions. Consequently, funding allocations should be commensurate with achievable benefits. Only through the combined efforts of concerned citizens, planners, engineers and legislators will we be able to abate the pollution that is impairing our nation's receiving waters.

APPENDIX H

References

1. EPA-600/2-77-064c - Nationwide Evaluation of Combined Sewer Overflows and and Urban Stormwater Discharges, Volume III - Characterization of Discharges: by R. Sullivan, et al., American Public Works Association, Chicago, IL. NTIS PB 272 107

2. EPA-600/8-77-014 - Urban Stormwater Management and Technology Update and User's Guide: by J. Lager, et al., Metcalf & Eddy, Palo Alto, CA. NTIS PB 275 654

3. EPA-600/2-77-047 - Urban Runoff Pollution Control Technology Overview: by R. Field, et al., USEPA, Storm and Combined Sewer Section, Edison, NJ. NTIS PB 264 452

4. "Potential of Urban Stormwater Impacts Based on Comparative Analysis of Wet and Dry Weather Pollutant Loads," by D. Ammon and R. Field, In: Urban Stormwater and Combined Sewer Overflow Impact on Receiving Water Bodies - Proceedings of the National Conference, Orlando, FL, November 26-28, 1979, EPA-600/9-80-056.

5. In-house Priority Pollutant Data, Storm and Combined Sewer Section, USEPA-MERL, Edison, NJ.

6. EPA-600/2-76-244 - Proceedings of Workshop on Microorganisms in Urban Stormwater: March 24, 1975, Storm and Combined Sewer Section, USEPA, Edison, NJ. NTIS PB 263 030

7. EPA-600/2-79-050f - Maximum Utilization of Water Resources in a Planned Community - Bacterial Characteristics of Stormwaters in Developing Rural Areas: by E.M. Davis, Rice University, Houston, TX. NTIS PB 80-129091

8. EPA-600/2-79-050a - Maximum Utilization of Water Resources in a Planned Community - Executive Summary: by W.G. Characklis, et al., Rice University, Houston, TX. NTIS PB 80-116205

9. EPA-600/2-77-087 - Microorganisms in Urban Stormwater: by V.P. Olivieri, et al., The Johns Hopkins University, Baltimore, MD. NTIS PB 272 245

10. EPA-600/8-79-004 - Urban Rainfall-Runoff-Quality Data Base: Update with Statistical Analysis: by W. Huber and J. Heaney, et al., University of Florida, Gainesville, FL. NTIS PB 80-113384

11. EPA-600/9-80-056 - Urban Stormwater & CSO Impact on Receiving Water Bodies: Proceedings of National Conference, Orlando, FL, November 26-28, 1979.
NTIS PB 81 155426

12. EPA-600/2-79-156 - Dissolved Oxygen Impact from Urban Storm Runoff: by Thomas N. Keefer, et al., The Sutron Corporation, Arlington, VA.
No NTIS

13. EPA-440/3-79-023 - A Statistical Method for the Assessment of Urban Stormwater: Load-Impacts-Controls: by D. Athayde, USEPA, Nonpoint Sources Branch, Washington, D.C.
No NTIS

14. EPA-600/2-78-135 - Dissolved Oxygen Measurements in Indiana Streams During Urban Runoff: by L.H. Ketchum, Jr., University of Notre Dame, IN.
NTIS PB 284 871

15. EPA-600/2-80-104 - Water Quality & Biological Effects of Urban Runoff on Coyote Creek - Phase I Preliminary Survey: by R. Pitt and M. Bozeman, Woodward-Clyde Consultants, San Francisco, CA.
NTIS PB 81-144487

16. EPA-600/2-79-155 - Verification of the Water Quality Impacts of Combined Sewer Overflows: by Thomas L. Meinholz, et al., (Rexnord) Metropolitan Sewage District of County of Milwaukee, WI.
No NTIS

17. Stormwater Management to Improve Lake Water Quality: by M.P. Wanielista, et al., University of Central Florida, Grant No. R-805580, (Publication Pending).

18. EPA-600/2-80-111 - Fate and Effects of Particulates Discharged by Combined Sewers and Storm Drains: by Richard D. Tomlinson, et al., Municipality of Metropolitan Seattle and University of Washington.

19. Evaluation of Urban Runoff and Combined Sewer Overflow Mutagenicity: Cooperative Agreement No. CR-806640.

20. EPA-600/8-80-035 - Urban Stormwater Management & Technology: Case Histories: by W.G. Lynard, et al., Metcalf & Eddy, Inc., Palo Alto, CA.
NTIS PB 81-107153

21. WPD 03-76-04 - Water Quality Management Guidance - Proceedings Urban Stormwater Management Seminars: Atlanta, GA, November 4-6, and Denver, CO, December 2-4, 1975, Edited by Dennis Athayde, USEPA, Water Planning Div., Washington, D.C.
NTIS PB 260 889

22. EPA-600/2-79-124 - Evaluation of Selective Erosion Control Techniques - Piedmont Region of S.E. United States: by H. Buxton and F.T. Caruccio, University of South Carolina, Columbia, SC.
NTIS PB 80-219645

23. EPA-600/2-78-208 - Demonstration of Erosion and Sediment Control Technology - Lake Tahoe Region of California: by C.A. White and A.L. Franks, California State Water Resources Control Board, Sacramento, CA.
NTIS PB 292 491

24. EPA-670/2-74-040 - Urban Stormwater Management and Technology An Assessment: by J.A. Lager and W.G. Smith, Metcalf & Eddy, Inc., Palo Alto, CA.
NTIS PB 240 687

25. EPA-600/9-78-035 - Urban Runoff Control Planning - Miscellaneous Reports Series: by M.B. McPherson, American Society of Civil Engineers, Marblehead, MA.
No NTIS

26. EPA-600/2-80-013 - Select Topics in Stormwater Management Planning for New Residential Developments: by R. Berwick, et al., Meta Systems, Cambridge, MA.
NTIS PB 80 187479

27. Storage/Sedimentation Facilities for Control of Storm and Combined Sewer Overflows Design Manual - draft final report: by W.M. Stallard, et al., Metcalf & Eddy, Inc., Palo Alto, CA.

28. EPA-670/2-73-077 - Combined Sewer Overflow Seminar Papers: by Storm and Combined Sewer Technology Branch, USEPA, Edison, NJ.
NTIS PB 231 836

29. EPA-670/2-75-046 - Rainfall-Runoff Relations on Urban and Rural Areas: by E.F. Brater and J.D. Sherrill, University of Michigan, Ann Arbor, MI.
NTIS PB 242 830

30. EPA-670/2-75-020 - Sewage System Monitoring and Remote Control: by T.R. Watt, et al., Detroit Metro Water Department, Detroit, MI.
NTIS PB 242 107

31. EPA-600/2-76-116 - Urban Stormwater Runoff Determination of Volumes and Flowrates: by B.C. Yen and V.T. Chow, University of Illinois, Urbana, IL.
NTIS PB 253 410

32. EPA-600/2-75-065 - An Assessment of Automatic Sewer Flow Samplers - 1975: by P.E. Shelley, EG&G Washington Analytical Services Center, Inc., Rockville, MD.
NTIS PB 250 987

33. EPA 600/2-75-027 - Sewer Flow Measurement - A State-of-the-Art Assessment: by P.E. Shelley and G.A. Kirkpatrick, EG&G Washington Analytical Services Center, Inc., Rockville, MD.
NTIS PB 250 371

34. EPA-600/9-76-014 - Areawide Assessment Procedures Manual - Vol. I, Vol. II and Vol. III: by USEPA Municipal Environmental Research Lab.-ORD, and Water Planning Division-OWHM.
No NTIS

35. EPA-600/2-76-286 - Cost Estimating Manual--Combined Sewer Overflow Storage and Treatment: by H.H. Benjes, Jr., Culp, Wesner, Culp, Inc., El Dorado Hills, CA.
NTIS PB 266 359

36. EPA-600/2-78-035 - Optimization and Testing of Highway Materials to Mitigate Ice Adhesion - Interim Report: by M. Krukar and J.C. Cook, Washington State University, Pullman, WA.
NTIS PB 280 927

37. Optimization and Testing of Highway Materials to Mitigate Ice Adhesion - draft final report: by J.C. Cook and M. Krukar, Washington State University, Pullman, WA.

38. EPA-670/2-74-045 - Manual for Deicing Chemicals: Application Practices: D.L. Richardson, Arthur D. Little, Inc., Cambridge, MA.
NTIS PB 239 694

39. EPA-670/2-74-033 - Manual for Deicing Chemical Storage and Handling: by D.L. Richardson, *et al*., Arthur D. Little, Inc., Cambridge, MA.
NTIS PB 236 152

40. EPA-660/2-74-073 - An Executive Summary of Three EPA Demonstration Programs in Erosion and Sediment Control: by B.C. Becker, *et al*., Hittman Associates, Columbia, MD.
GPO EP 1.23/2:660/2-74-073

41. EPA-600/8-76-001a - Erosion and Sediment Control Audio-Visual Training Program: Instruction Program: by the State of Maryland Water Resources Administration; Dept. of Transportation, The Federal Highway Administration; The U.S. Department of Agriculture, Soil Conservation Service; and USEPA, Office of Research and Development.
NTIS PB 256 901

42. EPA-600/8-76-001b - Erosion and Sediment Control Audio-Visual Training Program: Workbook: by the State of Maryland Water Resources Administration; Dept. of Transportation, The Federal Highway Administration; The U.S. Department of Agriculture, Soil Conservation Service; and USEPA, Office of Research and Development.
NTIS PB 258 471

43. EPA-R2-72-015 - Guidelines for Erosion and Sediment Control Planning and Implementation: by the Dept. of Water Resources, State of Maryland, and Hittman Assoc., Inc., Columbia, MD.
NTIS PB 213 119

44. EPA-660/2-74-071 - Programmed Demonstration for Erosion and Sediment Control Specialist: by T.R. Mills, et al., Water Resources Administration, State of Maryland.
GPO EP 1.23/2:660/2-74-071

45. 15030DTL05/70 - Urban Soil Erosion and Sediment Control: by National Association of Counties Research Foundation, Washington, D.C.
NTIS PB 196 111

46. EPA-670/2-75-011 - Physical and Settling Characteristics of Particulates in Storm and Sanitary Wastewater: by R.J. Dalrymple, et al., Beak Consultants for American Public Works Assoc., Chicago, IL.
NTIS PB 242 001

47. EPA-R2-73-145 - A Thermal Wave Flowmeter for Measuring Combined Sewer Flows: by P. Eshleman and R. Blase, Hydrospace Challenger, Inc., Rockville, MD.
NTIS PB 227 370

48. EPA-600/2-73-002 - A Portable Device for Measuring Wastewater Flow in Sewers: by M.A. Nawrocki, Hittman Associates, Inc., Columbia, MD.
NTIS PB 235 634

49. EPA-600/2-76-115 - A Passive Flow Measurement System for Storm and Combined Sewers: by K. Foreman, Grumman Ecosystems Corp., Bethpage, NY.
NTIS PB 253 383

50. EPA-600/2-76-243 - Wastewater Flow Measurement in Sewers Using Ultrasound: by R.J. Anderson and S.S. Bell, City of Milwaukee, WI.
NTIS PB 262 902

51. EPA-600/2-79-084 - Field Testing of Prototype Acoustic Emission Sewer Flowmeter: by K.M. Foreman, Grumman Aerospace Corp., Bethpage, NY.
NTIS PB 80-121544

52. EPA-600/2-76-006 - Design and Testing of Prototype Automatic Sewer Sampling System: by P. Shelley, EG&G Washington Analytical Service Center, Inc., Rockville, MD.
NTIS PB 252 613

53. EPA-670/2-75-002 - Suspended Solids Monitor: by John W. Liskowitz, et al., American Standard, Inc., New Brunswick, NJ.
NTIS PB 241 581

54. EPA-670/2-75-067 - Automatic Organic Monitoring System for Storm and Combined Sewers: by A. Tulumello, Ratheon Co., Portsmouth, RI.
NTIS PB 244 142

55. EPA-600/2-77-064b - Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges, Volume II - Cost Assessment and Impacts: by J.P. Heaney, et al., University of Florida, Gainesville, FL.
NTIS PB 266 005

56. EPA-600/2-76-275 - Storm Water Management Model Level I, Preliminary Screening Procedures: by J.P. Heaney, et al., University of Florida, Gainesville, FL.
NTIS PB 259 916

57. EPA-600/2-77-083 - Stormwater Management Model Level I, Comparative Evaluation of Storage Treatment and Other Management Practices: by J.P. Heaney, et al., University of Florida, Gainesville, FL.
NTIS PB 265 671

58. EPA-600/2-76-218 - Development and Application of a Simplified Stormwater Management Model: by John A. Lager, et al., Metcalf & Eddy, Inc., Palo Alto, CA.
NTIS PB 258 074

59. Areawide Stormwater Pollution Analysis with a Macroscopic Planning (ABMAC) Model: by Y.J. Litwin, et al., RAMLIT Associates, Berkeley, CA, and Metcalf & Eddy, Inc., Palo Alto, CA, Grant No. R-806357, (Publication Pending).

60. Macroscopic Planning Model (EPAMAC) for Stormwater and Combined Sewer Overflow Control: Application Guide and User's Manual: by W.G. Smith and M.E. Strickfaden, Metcalf & Eddy, Inc., Palo Alto, CA, Contract No. 68-03-2877, (Publication Pending).

61. EPA-600/2-79-100 - Level III: Receiving Water Quality Modeling for Urban Stormwater Management: by M. Medina, Duke University, Durham, NC.
NTIS PB 80-134406

62. Storm Water Management Model User's Manual - Version III - draft final report: by W.C. Huber, et al., University of Florida, Gainesville, FL, Grant No. R-802411.

63. EPA-600/2-80-011 - Quantity-Quality Simulation (QQS): A Detailed Continuous Planning Model for Urban Runoff Control - Volume I: Model Description, Testing and Applications: by W.F. Geiger and H.R. Dorsch, Dorsch Consult Ltd., Toronto, Ontario.
NTIS PB 80-190507

64. EPA-600/2-80-116 - Quantity-Quality Simulation (QQS): A Detailed Continuous Planning Model for Urban Runoff Control - Volume II: User's Manual: by W.F. Geiger and H.R. Dorsch, Dorsch Consult Ltd., Toronto, Ontario.
NTIS PB 80-221872

65. EPA-670/2-75-022 - Urban Stormwater Management Modeling and Decision-Making: by J.P. Heaney and W.C. Huber, University of Florida, Gainesville, FL.
NTIS PB 242 290

66. EPA-670/2-75-017 - Stormwater Management Model User's Manual - Version II: by W.C. Huber, et al., University of Florida, Gainesville, FL.
No NTIS

67. 11020FAQ03/71 - Dispatching Systems for Control of Combined Sewer Losses: by Metro. Sewer Board, St. Paul, MN.
NTIS PB 203 678

68. EPA-670/2-74-022 - Computer Management of a Combined Sewer System: by C.P. Leiser, Municipality of Metropolitan Seattle, Seattle, WA.
NTIS PB 235 717

69. 11022ELK12/71 - Maximizing Storage in Combined Sewer Systems: by Municipality of Metropolitan Seattle, WA.
NTIS PB 209 861

70. EPA-670/2-75-041 - Storm Water Management Model: Dissemination and User Assistance: J.A. Hagerman and F.R.S. Dressler, University City Science Center, Philadelphia, PA.
NTIS PB 242 544

71. EPA-670/2-75-065 - Short Course Proceedings, Applications of Stormwater Management Models: by F. DiGiano, et al., University of Massachusetts, Amherst, MA.
NTIS PB 247 163

72. EPA-600/2-77-065 - Short Course Proceedings, Applications of Stormwater Management Model - 1976: by F. DiGiano, et al., University of MA, Amherst, MA.
NTIS PB 265 321

73. EPA-600/2-76-175a - Assessment of Mathematical Models for Storm and Combined Sewer Management: by A. Brandstetter, Battelle, Pacific Northwest Lab., Richland, WA.
NTIS PB 259 597

74. 11034DUY03/72 - Investigation of Porous Pavements for Urban Runoff Control: by E. Thelen, W.C. Grover, A.J. Hoiberg, and T.I. Haigh, The Franklin Institute Research Lab., Philadelphia, PA.
NTIS PB 227 516

75. EPA-600/2-79-050c - Maximum Utilization of Water Resources in a Planned Community - Application of the Stormwater Management Model: Volume I: by E. Diniz and W. Espey, Jr., Espey, Huston & Associates, Inc., Austin, TX.
NTIS PB 80-121437

76. Best Management Practices Implementation - Great Lakes Demonstration Program, Rochester, NY: by C.B. Murphy, O'Brien & Gere Engineers, Inc., Syracuse, NY, Grant No. G005334 (Publication Pending).

77. EPA-600/2-80-135 - Porous Pavement: Phase I Design & Operational Criteria: by E.V. Diniz, Espey, Huston & Associates, Inc., Albuquerque, NM.
NTIS PB 81-104796

78. EPA-600/2-77-033 - Methods for Separation of Sediment from Storm Water at Construction Sites: by J.F. Ripken, et al., University of Minnesota, Minneapolis, MN.
NTIS PB 262 782

79. EPA-600/2-79-076 - Laboratory Evaluation of Methods to Separate Fine Grained Sediment from Stormwater: by L.M. Bergstedt, et al., St. Anthony Falls Hydraulic Laboratory, Minneapolis, MN.
NTIS PB 80-121528

80. EPA-670/2-74-026 - The Swirl Concentrator as a Grit Separator Device: by R.H. Sullivan, et al., American Public Works Association, Chicago, IL.
NTIS PB 233 964

81. EPA-600/2-76-271 - The Swirl Concentrator for Erosion Runoff Treatment: by R.H. Sullivan, et al., American Public Works Association, Chicago, IL.
NTIS PB 266 598

82. EPA-600/2-77-185 - Field Prototype Demonstration of the Swirl Degritter: by R.H. Sullivan, et al., American Public Works Association, Chicago, IL.
NTIS PB 272 668

83. EPA-600/2-78-122 - The Swirl Primary Separator: Development and Pilot Demonstration: by R.H. Sullivan, et al., American Public Works Association, Chicago, IL.
NTIS PB 286 339

84. EPA-R2-72-081 - Water Pollution Aspects of Street Surface Contaminants: by J.D. Sartor and G.B. Boyd, URS Research Co., San Mateo, CA.
NTIS PB 214 408

85. EPA-R2-73-283 - Toxic Materials Analysis of Street Surface Contaminants: by R.E. Pitt, and G. Amy, URS Research Co., San Mateo, CA.
NTIS PB 224 677

86. EPA-600/2-75-004 - Contributions of Urban Roadway Usage to Water Pollution: by D.G. Shaheen, Biospherics Inc., Rockville, MD.
NTIS PB 245 854

87. EPA-600/2-79-161 - Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Practices: by R.E. Pitt, Woodward-Clyde Consultants, San Francisco, CA.
NTIS PB 80-108988

88. Bellevue (WA) Street Sweeping Demonstration Project - First Annual Report, Cooperative Agreement # CR-805929, U.S. Environmental Protection Agency.

89. EPA-600/2-77-217 - Urban Runoff Treatment Methods, Volume I - Non-Structural Wetland Treatment: by E.A. Hickock, et al., Eugene A. Hickock and Associates, Wayzata, MN.
NTIS PB 278 172

90. Treatment of Stormwater Runoff by a Marsh/Flood Basin - draft final report: by Y.J. Litwin, et al., RAMLIT Associates, Berkeley, CA, and Association of Bay Area Governments, Berkeley, CA, Grant No. R-806357.

91. The Use of Wetlands for Water Pollution Control - draft final report: by E. Chan, et al., Association of Bay Area Governments, Berkeley, CA, and RAMLIT Associates, Berkeley, CA, Grant No. R-806357.

92. EPA-600/2-77-051 - Catchbasin Technology Overview and Assessment: by J. Lager, et al., Metcalf & Eddy, Inc., Palo Alto, CA, in association with Hydro-Research-Science, Santa Clara, CA.
NTIS PB 270 092

93. Evaluation of Catchbasin Monitoring - draft final report: by G.L. Aronson, et al., Environmental Design & Planning, Inc., Allston, MA, Grant No. R-804578.

94. "An Update on EPA's Storm and Combined Sewer Research," by R. Field, In: Deeds & Data - Water Pollution Control Federation Highlights, Volume 18, Number 6, June, 1981.

95. 11022DMU07/70 - Combined Sewer Regulator Overflow Facilities: by American Public Works Association, Chicago, IL.
No NTIS

96. EPA-625/2-77-012 - Swirl Device for Regulating and Treating Combined Sewer Overflows: EPA Technology Transfer Capsule Report, Prepared by R. Field and H. Masters, USEPA, Edison, NJ, ERIC 2012 (Cincinnati), 1977.

97. EPA-R2-72-008 - The Swirl Concentrator as a Combined Sewer Overflow Regulator Facility: by R. Sullivan, American Public Works Association, Chicago, IL.
NTIS PB 214 687

98. EPA-670/2-73-059 - The Dual-Functioning Swirl Combined Sewer Overflow Regulator/Concentrator: by R. Field, USEPA, Edison, NJ.
NTIS PB 227 182/3

99. EPA-670/2-74-039 - Relationship between Diameter and Height for Design of a Swirl Concentrator as a Combined Sewer Overflow Regulator: by R.H. Sullivan, et al., American Public Works Association, Chicago, IL.
NTIS PB 234 646

100. Design Manual-Secondary Flow Pollution Control Devices - draft final report: by R.H. Sullivan, et al., APWA, Grant No. R-803157.

101. EPA-600/2-75-062 - The Helical Bend Combined Sewer Overflow Regulator: by R.H. Sullivan, et al., American Public Works Association, Chicago, IL.
NTIS PB 250 619

102. Demonstration of Swirl and Helical Bend Regulators as Storm Sewer Control Devices, Cooperative Agreement Demonstration No. CS-805795.

103. 11020FAL03/71 - Evaluation of Storm Standby Tanks, Columbus, OH: by Dodson, Kinney & Lindblom, Columbus, OH.
NTIS PB 202 236

104. EPA-600/2-77-046 - Cottage Farm Combined Sewer Detention and Chlorination Station, Cambridge, MA: by Commonwealth of MA Metropolitan District Commission, MA.
NTIS PB 263 292

105. 11023---08/70 - Retention Basin Control of Combined Sewer Overflows: by Springfield Sanitary District, Springfield, IL.
NTIS PB 200 828

106. EPA-R2-72-070 - Storage and Treatment of Combined Sewer Overflows: by the City of Chippewa Falls, WI.
NTIS PB 214 106

107. EPA-600/2-75-071 - Detention Tank for Combined Sewer Overflow - Milwaukee, WI Demonstration Project: by Consoer, Townsend and Associates, Chicago, IL.
NTIS PB 250 427

108. EPA-670/2-75-010 - Multi-Purpose Combined Sewer Overflow Treatment Facility, Mount Clemens, Michigan: by V.U. Mahida, et al., Spalding, DeDecker & Associates, Inc., Madison Heights, MI.
NTIS PB 242 914

109. 11022DPP10/70 - Combined Sewer Temporary Underwater Storage Facility: by Melpar, Falls Church, VA.
NTIS PB 197 669

110. 11022ECV09/71 - Underwater Storage of Combined Sewer Overflows: by Karl R. Rohrer Assoc., Inc., Akron, OH.
NTIS PB 208 346

111. 11020DWF12/69 - Control of Pollution by Underwater Storage: by Underwater Storage, Inc., Silver, Schwartz, Ltd., Joint Venture, Washington, DC.
NTIS PB 191 217

112. EPA-600/2-76-272 - Demonstration of Void Space Storage with Treatment and Flow Regulation: by Karl R. Rohrer Assoc., Inc., Akron, OH.
NTIS PB 263 032

113. 11020---02/71 - Deep Tunnels in Hard Rock: by College of Applied Science and Engineering and University Extension, University of Wisconsin, Milwaukee, WI
NTIS PB 210 854

114. EPA-R2-73-242 - Temporary Detention of Storm and Combined Sewage in Natural Underground Formations: by City of St. Paul, St. Paul, MN.
GPO EP 1.23/2:73-242

115. EPA-600/2-80-014 - Lawrence Avenue Underflow Sewer System-Interim Report-Planning and Construction: by L. Koncza, et al., City of Chicago, Chicago, IL.
NTIS PB 81-145708

116. EPA-600/2-77-069a - Screening/Flotation Treatment of Combined Sewer Overflows, Volume I - Bench-Scale and Pilot Plant Investigations: by M.K. Gupta, et al., Envirex, Environmental Science Div., Milwaukee, WI.
NTIS PB 272 834

117. EPA-600/2-79-106a - Screening/Flotation Treatment of Combined Sewer Overflows: Volume II: Full-Scale Operation, Racine, WI: by T.L. Meinholz, Envirex, Inc., Milwaukee, WI.
NTIS PB 80-130693

118. 11020FDC01/72 - Screening/Flotation Treatment of Combined Sewer Overflows: by the Ecology Division, Rex Chainbelt, Inc., Milwaukee, WI.
No NTIS

119. EPA-600/2-79-085 - Combined Sewer Overflow Treatment by Screening and Terminal Ponding - Fort Wayne, IN: by D.H. Prah and P.T. Brunner, City of Fort Wayne, IN.
NTIS PB 80-119399

120. 11023FDD07/71 - Demonstration of Rotary Screening for Combined Sewer Overflows: by City of Portland, Dept. of Public Works, Portland, OR.
NTIS PB 206 814

121. 11023FDD03/70 - Rotary Vibratory Fine Screening of Combined Sewer Overflows: by Cornell, Howland, Hayes and Merryfield, Corvallis, OR.
NTIS PB 195 168

122. 11020EXV07/69 - Strainer/Filter Treatment of Combined Sewer Overflows: by Fram Corporation, East Providence, RI.
NTIS PB 185 949

123. 11023EYI04/72 - High-Rate Filtration of Combined Sewer Overflows: (Cleveland): by R. Nebolsine, et al., Hydrotechnic Corp., New York, NY.
NTIS PB 211 144

124. EPA-600/2-79-015 - Dual Process High-Rate Filtration of Raw Sanitary Sewage and Combined Sewer Overflows: (Newtown Creek), by H. Innerfeld, et al., New York City Dept. of Water Resources, New York, NY.
NTIS PB 296 626/AS

125. EPA-600/2-75-033 - Treatment of Combined Sewer Overflows by Dissolved Air Flotation: by T.A. Bursztynsky, et al., Engineering Science, Inc., Berkeley, CA.
NTIS PB 248 186

126. EPA-600/2-78-209 - Treatment of Combined Sewer Overflows by High Gradient Magnetic Separation - On-Site Testing with Mobile Pilot Plant Trailer: by D.M. Allen, Sala Magnetics, Cambridge, MA.
NTIS PB 292 329

127. EPA-600/2-77-015 - Treatment of Combined Sewer Overflows by High Gradient Magnetic Separation: by J. Oberteuffer, et al., Sala Magnetics, Cambridge, MA.
NTIS PB 264 935

128. EPA-R2-73-149 - Physical-Chemical Treatment of Combined and Municipal Sewage: by A.J. Shuckrow, et al., Pacific NW Lab., Battelle Memorial Institute, Richland, WA.
NTIS PB 219 668

129. 11023EV006/70 - Microstraining and Disinfection of Combined Sewer Overflows: by Cochrane Div., Crane Co., King of Prussia, PA.
NTIS PB 195 67

130. EPA-R2-73-124 - Microstraining and Disinfection of Combined Sewer Overflows-Phase II: G.E. Glover, and G.R. Herbert, Crane Company, King of Prussia, PA.
NTIS PB 219 879

131. EPA-670/2-74-049 - Microstraining and Disinfection of Combined Sewer Overflows-Phase III: by M.B. Maher, Crane Company, King of Prussia, PA.
NTIS PB 235 771

132. EPA-670/2-75-021 - Bench-Scale High-Rate Disinfection of Combined Sewer Overflows with Chlorine and Chlorine Dioxide: by P.E. Moffa, et al., O'Brien & Gere Engineers, Inc., Syracuse, NY.
NTIS PB 242 296

133. EPA-600/2-79-134 - Disinfection/Treatment of Combined Sewer Overflows, Syracuse. New York: by F. Drehwing, et al., O'Brien & Gere Engineers, Inc., Syracuse, NY.
NTIS PB 80-113459

134. EPA-670/2-73-071 - Utilization of Trickling Filters for Dual-Treatment of Dry and Wet-Weather Flows: by P. Homack, et al., E.T. Killam Assoc., Inc., Millburn, NJ.
NTIS PB 231 251

135. EPA-670/2-75-019 - Biological Treatment of Combined Sewer Overflow at Kenosha, WI: by R.W. Agnew, et al., Envirex, Milwaukee, WI.
NTIS PB 242 126

136. EPA-670/2-74-050 - Combined Sewer Overflow Treatment by the Rotating Biological Contactor Process: by F.L. Welsh, and D.J. Stucky, Autotrol Corp., Milwaukee, WI.
NTIS PB 231 892

137. EPA-660/2-73-006a - Wastewater Treatment Reuse by Land Application - Volume I: Summary: by Charles E. Pound and Ronald W. Crites, Metcalf & Eddy, Palo Alto, CA.
No NTIS

138. "Industrial Reuse of Urban Stormwater," by R. Field and C. Fan, In: J. Env. Eng. Div ASCE, Vol. 107, No. EE1, February, 1981.

139. EPA-R2-73-139 - The Beneficial Use of Stormwater: by C.W. Mallory, Hittman Associates, Columbia, MD.
NTIS PB 217 506

140. EPA-670/2-75-010 - Multi-Purpose Combined Sewer Overflow Treatment Facility, Mount Clemens, Michigan: by V.U. Mahida, F.J. DeDecker, Spalding, DeDecker Associates, Inc., Madison Heights, MI.
NTIS PB 242 914

141. Storm and Combined Sewer Section Publications Bibliography, U.S. Environmental Protection Agency, Edison, New Jersey, March, 1981.